



## A collage of images illustrating various aspects of food processing and agriculture. The central image shows a man in a red shirt and glasses examining a sample through a magnifying glass. Surrounding this are several other scenes: a man working at a desk, a woman working in a food processing facility, a man working in a field, a tractor in a field, and a large building in the background. The collage is set against a blue background with a grid pattern.

# 2014 Annual Progress Report & 2015 Research Plans

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## **Mission Statement**

**Southern Insect Management Research Unit  
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P.O. Box 346  
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The mission of the Southern Insect Management Research Unit (SIMRU) is to generate new knowledge of arthropod pest biology, ecology and management and integrate this knowledge into contemporary farming systems that will promote economical and environmentally stable pest management practices for the southern U.S.

The vision of SIMRU is to be a recognized center of innovation for negating agricultural pest problem through deployed scientific knowledge of pest biology, ecology and management options.

## **Disclaimer and Purpose of Report**

This report summarizes progress made on research objectives for 2014 and plans for research activities in 2015.

Many of the results are preliminary and others are being released through established channels. Therefore, this report is not intended for publication and should not be referred to in literature citations.

Intent of this report is to give the reader an overview of the Southern Insect Management Research Unit (SIMRU) activities. The activities (progress and plans) address the research unit mission. Formal annual reports of research progress as submitted to the CRIS system are included in the summary.

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## Overall Summary and Perspective of 2014 SIMRU Activities

USDA entomologists have been working on cotton insects in Stoneville, Mississippi since 1934. Cotton insect pest problems are still a focus of SIMRU research 80 years later, but the Unit addresses a much broader range of arthropod pest problems on all southern crops. This includes a wide range of basic and applied explorations of insect pest biology and ecology that provide future foundation for environmentally sound and economically viable pest management systems. Research projects, scientific personnel and funding levels are dynamic, but the commitment to develop innovative and sustainable pest management for southern row crops continues as the core focus for the Unit.

A few important changes in SIMRU personnel occurred in 2014 including the retirement of Dr. Gordon Snodgrass. Dr. Snodgrass' contributions to our understanding of tarnished plant bug are unmatched. His impact on SIMRU, Delta agriculture and many of the entomologists in the Midsouth are numerous and significant. The Unit in collaboration with Mississippi State University scientists, and leadership of Drs. Kristine Edwards and Katherine Parys, published a *Special Issue of Midsouth Entomologist* devoted to tarnished plant bug that highlights tarnished plant bug research in Mississippi, much of which was directly influenced by Dr. Snodgrass. Dr. Nathan Little, a previous Cat 2 scientist in SIMRU and a graduate of Mississippi State University, joined SIMRU as a Cat 1 scientist in January and is developing a new research program associated with field crops and pest resistance to insecticides and transgenic crops. Dr. Yu Cheng Zhu completed the second year of his special assignment to study honey bee toxicology in collaboration with Dr. John Adamczyk at the USDA Southern Horticultural Research Laboratory in Poplarville, Mississippi. Sandy West, a long-time Biological Science Technician in Dr. Zhu's research group, left SIMRU to further her expanding career as a novelist. Julian Henry, a long-time Biological Science Aid, obtained a permanent position with the Department of Justice. Randy Luttrell served as Acting Research Leader of the Biological Control of Pests Research Unit and split his time between SIMRU and BCPRU during 2014. SIMRU scientists and administrative staff provided additional oversight of the Unit in 2014, including relocation of the Unit to 3<sup>rd</sup> floor of Bldg. 1 of the Jamie Whitten Delta States Research Center. Dr. Maribel Portilla and Chad Roberts were promoted in 2014 demonstrating the continuing development of scientific talent in the unit.

SIMRU's close connection and commitment to outreach, scientific education, and the Delta community was recognized at several levels. In August, Randy Luttrell representing SIMRU as one of the USDA ARS Mid-South Area groups involved, accepted the "2014 Outstanding Accomplishment in STEM Education Support" award from the Southeast Region, Federal Laboratory Consortium at the United States Center for Disease Control in Atlanta, Georgia. In November, SIMRU scientists organized a "STEAM" (science, technology, engineering, agricultural, mathematics) workshop for students from Coleman and T. L. Weston Middle Schools. This was a coordinated outreach program with the U.S. Department of Agriculture, Office of Research, Education, and Economics and networked similar outreach activities with Washington D.C.; Auburn, Alabama; College Station, Texas; Lubbock, Texas; New Orleans, Louisiana; Stoneville (SIMRU), Mississippi; and Stuttgart, Arkansas. SIMRU's insect rearing program continues to provide insects to the USDA Future Scientists Program around the U.S. Kenya Dixon and Chris Johnson served as Science Fair judges in January. Tabatha Nelson and Yolanda Harvey volunteered to assist with the Youth Motivation Task Force Conference at Mississippi Valley State University in November. Randy Luttrell participated in the Washington County Leadership Development program by discussing insect research at Stoneville and providing tours of Stoneville research facilities. Randy Luttrell also provided a guest lecture to the Greenville Renaissance Scholars program at the E.E. Bass Center in Greenville, Mississippi in June. Nineteen of the twenty 2014 student employees in SIMRU presented poster presentations of their learning experiences in August. These presentations are posted on SIMRU's website (<http://www.ars.usda.gov/Main/docs.htm?docid=23857>) along with papers and presentations of summer employees since 2011. Interest among high school and college students in part-time positions in SIMRU remains high and a positive indication of SIMRU's

commitment to scientific education. SIMRU continues to maintain close interactions with universities in the region. The faculty of the Department of Biochemistry, Molecular Biology, Entomology and Plant Pathology of Mississippi State University toured the facility and interacted with SIMRU scientists in December. Dr. Jeff Dean, the new department head organized the interaction and is working to strengthen ties to our ARS programs.

Research planning dominated much of the scientific effort in SIMRU during 2014. Plans for the next cycle of research projects in National Program 304 Crop Protection and Quarantine were initiated with involvement and input from all SIMRU scientists. This included numerous internal meetings and web-conferences with National Programs (NP) and other NP 304 researchers. Three new core projects have been developed and submitted to the office of Scientific Quality Review (OSQR) for review. Dr. O. P. Perera serves as the Lead Scientist for a proposed new project “*Innovative Strategies for Insect Resistance Management in Bt Cotton*”. Drs. Clint Allen, Nathan Little, Randy Luttrell and the vacant vice-Snodgrass position will conduct research on this project. Dr. Maribel Portilla is Lead Scientist for the project “*Alternative Approaches to Tarnished Plant Bug Control*”. Drs. Katherine Parys, O.P. Perera, Randy Luttrell, and the vacant vice-Snodgrass position will conduct research under this project. Dr. Clint Allen is the Lead Scientist for the project “*Integrated Insect Pest and Resistance Management in Corn, Cotton, Sorghum, Soybean and Sweet Potato*”. All SIMRU scientists have a component of their time dedicated to research in this project. These three administer and finance all SIMRU activities and are the overall framework for research proposed over the next five years. The Unit also has active Specific Cooperative Agreements with Alcorn State University, the Delta Research and Extension Center at Stoneville, and Mississippi State University, a number of research collaborations with commodity groups, biotech industries, other universities and other ARS research units.

SIMRU scientists have strong collaborations with the Midsouth Entomologists and routine involvement with regional and national cooperative projects. SIMRU scientists have served as members of graduate student advisory committees at Mississippi State University, Louisiana State University, and the University of Arkansas in recent years. SIMRU scientists participated in a wide diversity of professional and scientific meetings in 2014 including the National Sweetpotato Collaborators meeting in Dallas, Texas; the Beltwide Cotton Conference in New Orleans, Louisiana; the Southeastern Branch of the Entomological Society of America meeting in Greenville, South Carolina; the Mississippi Entomological Association meeting in Starkville, Mississippi; the Midsouth Entomologist Working Group meeting in Cascoe, Arkansas; the Mississippi State University Row Crops Short Course in Starkville, Mississippi; the Entomological Society of America meeting in Austin, Texas; the Arthropod Genomics Symposium in Champaign, Illinois; a special Arthropod Genomics Research Workshop in Beltsville, Maryland; and a Board of Agriculture, National Academy of Sciences meeting on Pesticide Resistance in Washington, D.C. Larry Adams and Chris Johnson continue to build linkages to minority farmers growing sweetpotatoes in the Delta. Donny Adams, Nathan Little, Clint Allen and Lou Andrews are providing important structure for on-farm research studies across the Delta. Owen Houston and Phil Powell are enhancing SIMRU’s field research through development, a top-notch field research facility.

The following report summarizes the most important SIMRU activities in 2014, the actual research completed, the publications submitted and published, and the titles of scientific presentations delivered to diverse clientele. The report also includes proposed research plans for 2015. Our research program is devoted to the agricultural clientele that we serve. We value you and appreciate your suggestions to improve our work.

Randy Luttrell, Research Leader

## CRIS Projects

**Research Project:** *Insecticide Resistance Management and New Control Strategies for Pests of Corn, Cotton, Sorghum, Soybean, and Sweet Potato*

**Project Scientists:** Kerry Clint Allen (Lead Scientist), Randall Luttrell, Katherine Parys, Maribel Portilla, OP Perera, Yu Cheng Zhu, Vice-Snodgrass

**Project Number:** 6402-22000-063-00D

**Date:** Sep 01, 2010

**Project Type:** Appropriated Start

**End Date:** Aug 31, 2015

**Objectives:** The long-term objective of this project is to develop an improved understanding of how the changing cropping landscape impacts insecticide resistance development and management of various insect pest species in order to increase profitability and sustainability of mid-South row crops. Objective 1: Improve tarnished plant bug control and insecticide resistance management by gaining new information on the pest's ecology and biology using multi-disciplinary approaches, e.g. molecular genetic tools, stable carbon isotope analysis, gene expression and proteomics, and insecticide resistance assays coupled with field sampling. Objective 2: Determine the effect of bollworm ecology (corn earworm) on resistance to pyrethroid insecticides by developing and utilizing genetic markers linked to resistance traits, stable carbon isotope analysis, gossypol detection in adult insects, and insecticide resistance monitoring. Objective 3: Develop pest control strategies for the U.S. Mid-South's Early Soybean Production System by determining accurate treatment thresholds, understanding the impact of changing cropping systems on farm-scale pest ecology, and developing effective insecticide resistance management practices for the stink bug complex, three-cornered alfalfa hopper, bean leaf beetle and soybean looper. Objective 4: Improve low input systems of pest control for sweet potato by evaluating the efficacy and proper use of newly registered insecticides to enhance their integration with crop rotation and other low cost control strategies.

**Approach:** We plan to improve tarnished plant bug control and insecticide resistance management by gaining new information on the pest's ecology and biology using multi-disciplinary approaches. Analytical techniques, such as stable carbon isotope analysis, will be used to determine the influence of C4 host plants, such as field corn or pigweed, on populations of tarnished plant bug adults infesting cotton fields. This information will identify sources of tarnished plant bugs that may lead to alternative control measures prior to infestations into cotton fields. Tarnished plant bug populations will be monitored for resistance to various classes of insecticides commonly used by mid-South producers. This will provide real-time information to decision makers that will allow them to adjust their control recommendations based on the type of resistance that is found in their area of the mid-South. Detoxification enzyme activity surveys will be conducted in an effort to correlate and quantify insecticide resistance levels in field populations of the tarnished plant bug. Molecular genetics techniques will be conducted on tarnished plant bug populations that could lead to assays to evaluate the extent of field resistance in tarnished plant bug populations and provide input for insect management decisions. We also plan to determine the effect of bollworm ecology (corn earworm) on resistance to pyrethroid insecticides. Analytical techniques, such as stable carbon isotope analysis and a gossypol detection technique, will be used to determine the impact of bollworm larval plant host on pyrethroid resistance levels measured in adults collected from pheromone traps. Molecular genetics tools will be used to identify candidate genes and biological pathways associated with insecticide resistance in bollworm populations. Successful identification of loci associated with insecticide resistance and the development of genetic markers for those will provide a method to obtain quantitative estimates of field evolved resistance by estimating the allele frequencies via population studies. We will also develop pest control strategies for the U.S. Mid-South's Early Soybean Production System by determining accurate treatment thresholds and developing effective insecticide

resistance management practices for the stink bug complex and bollworm. Field studies will be conducted to evaluate treatment thresholds for stink bugs and bollworms in early season soybeans. Stink bug populations will be monitored for potential resistance to various classes of insecticides, and this effort will provide real-time information to decision makers regarding the proper use of insecticides for control of these pests. We also plan to improve low input systems of pest control for sweet potato by evaluating the efficacy and proper use of newly registered insecticides to enhance their integration with crop rotation and other low cost control strategies. Field and laboratory studies will be conducted to determine the impact of crop rotation on populations of insect pests of sweet potatoes, as well as information of insecticide efficacy and proper application techniques.

**Summary:** Trends from insecticide resistance monitoring of tarnished plant bug indicated that susceptibilities to pyrethroid and organophosphate insecticides are stable and possibly slightly increasing. The slight increase in susceptibility to pyrethroids and organophosphates are probably due to increased usage of some newer insecticides. Tarnished plant bug populations continue to be susceptible to thiamethoxam and novaluron. This information is used by consultants and producers when selecting insecticides for tarnished plant bug control. Microsatellite markers were used to examine the population genetics of tarnished plant bug in the MS Delta. Results indicated that the proportion of two genetic clusters changed over time, possibly due to genetic drift or migration. This information is important for understanding the movement of tarnished plant bug and the implementation of optimum control and resistance management strategies. An updated host plant list for tarnished plant bug is nearing completion. In studies related to bollworm, the proportion of bollworms and tobacco budworms inhabiting soybean is being examined. From recent collections in the MS Delta, it is estimated that approximately 10 % were tobacco budworm with the remainder bollworm. Field studies examining the economic benefits of Bt transgenic and non-Bt cotton with and without insecticide sprays are being continued. Bt cotton plots required fewer insecticide applications than non-Bt cotton, but the benefits of these sprays varied by location. Field plots have been established in producer fields within the MS Delta to examine the potential damage of natural populations of stink bugs and lepidopteran pests on soybean. The temporal occurrence of stink bug species is being examined across the MS Delta. Low numbers of stink bugs have been encountered the past few years. The kudzu bug is increasing its populations on soybean in the lower MS Delta and spreading to other areas of the state. Baseline susceptibilities of kudzu bugs in adult vial tests to pyrethroid and organophosphate insecticides are underway. A fall armyworm strain collected from Puerto Rico with high levels of resistance to the Bt protein, Cry1F was examined for resistance to non-Bt insecticides. Results indicate that multiple/cross resistances may have developed in the PR strain to both Bt toxins and conventional insecticides. To assess pesticide toxicity on honey bee,  $LC_{50s}$  on several pesticides is being obtained. Evaluations of control of important pests of sweet potatoes continues. Control of sugarcane beetles with various insecticide regimens in sweet potatoes is being examined. The importance of taking soil samples for monitoring and decisions regarding treatments for nematodes in sweet potato is being demonstrated.

**Research Project:** *Control of Tarnished Plant Bugs by Biocontrol and Other Methods*

**Project Scientists:** Maribel Portilla (Lead Scientist), Randall Luttrell, Vice-Snodgrass

**Project Number:** 6402-22000-064-00D

**Project Type:** Appropriated

**Start Date:** Jan 03, 2011

**End Date:** Jan 02, 2015

**Objectives:** Determine the effect of temperature and reproductive state on susceptibility of tarnished plant bugs to *Beauveria (B.) bassiana* (ARSEF 8889). Determine the effect of exposure to insect growth regulators (IGRs) and *B. Bassiana* (ARSEF 8889) on immature tarnished plant bug survival. Determine the effect of host plant and application timing (season) on susceptibility of tarnished plant bugs treated with ARSEF 8889 and IGRs (in situ).

**Approach:** The effect of temperature and reproductive state on the susceptibility of tarnished plant bugs to *Beauveria (B.) bassiana* (ARSEF 8889) will be determined in replicated laboratory tests. The two reproductive states tested will be normal reproductive adults and nymphs and diapausing adults and nymphs that produce diapausing adults. Temperatures tested will range from 10°C to 30°C. Insect growth regulators (IGRs) will be tested with nymphs in replicated laboratory tests to determine which IGRs are effective and the rate at which to use them. The most effective IGR(s) will be tested in laboratory tests in combination with ARSEF 8889 to determine the most effective combination treatment. Results from the laboratory tests will be tested in the field in replicated tests in cotton (for in-season plant bug control) and in the fall and winter on wild host plants (for control of the diapausing overwintering generation). The effect of IGRs and ARSEF 8889 treatment on beneficial arthropod populations will be evaluated in the field tests and with additional laboratory tests.

**Summary:** ARSEF 8889 and novaluron (Diamond) used alone and in combination were evaluated by Dr. Gordon Snodgrass for control of tarnished plant bugs in large (ca. 1 acre) replicated plots of cotton at Stoneville, MS, in June and July 2012. ARSEF 8889 ( $8 \times 10^{12}$ ) used in combination with novaluron (9 oz/acre) was as good as standard insecticides (acephate 1 lb AI/acre, sulfoxaflur 2.5 oz/acre) in reducing numbers of tarnished plant bug adults and nymphs in the cotton. The combination treatment had the highest yield of cotton in the test and had a much smaller impact on beneficial arthropods than the standard insecticide treatment. ARSEF 8889 and GHA strain were evaluated in 2013 in small (8 rows x 50 feet) replicated plots to see the effect of morning and night application with both strains combined with two surfactants. Spores of each isolate showed their inability to survive exposure to solar radiation, which affects the use of this entomopathogenic fungus for the control of the TPB. However, 50% mortality of TPB adults was obtained by direct spray or by contact using ARSEF 8889 + Tween-80 with spores rates commercially recommended ( $6.5 \times 10^{12}$  per acre). Laboratory studies showed that ARSEF 8889 was more effective than *Beauveria bassiana* Strain GHA at low temperatures against plant bugs.  $LC_{50}$ s and  $LD_{50}$ s estimated in this experiment will be used in a preliminary experiment in weed plots during winter 2014.

**Research Project:** *Effect of Resistance on Insect Pest Management in Transgenic Cotton*

**Project Scientists:** OP Perera (Lead Scientist), Kerry Clint Allen, Nathan Little, Randall Luttrell, Katherine Parys

**Project Number:** 6402-22000-065-00D

**Start Date:** April 26, 2011

**Project Type:** Appropriated

**End Date:** March 31, 2016

**Objectives:** Determine the impact of a changing cropping landscape on host plant ecology and insect resistance management practices for bollworm using analytical techniques. Determine gene flow and migration patterns by analyzing tobacco budworm and bollworm populations in temporal and spatial scales using genetic and/or empirical/mathematical approaches. Identify possible mechanisms of resistance to Bt toxins by profiling gene expression patterns and develop a marker based genetic linkage map.

**Approach:** More than 95% of the second generation bollworm within each growing season utilizes field corn as a host. Impact of corn plants expressing multiple Bt toxins on the bollworm populations will be studied by comparing historical pheromone trap data with current and future population estimates influenced by increased acreages of Bt corn expressing multiple Bt toxins. Stable carbon isotope analysis will be used to identify bollworms using corn as a host plant. Influence of local cropping landscape on bollworm populations will be studied using sentential plots of conventional and Bt corn and cotton and early maturing soybeans. Large field cages will be used to evaluate the impact of pyramided-gene Bt corn hybrid/refuge system on resistance management strategies. Expressed genes of tobacco budworm and bollworm will be identified by transcriptome sequencing, and genetic markers developed from polymorphic nucleotide regions will be used in ecological genetic studies of tobacco budworm and bollworm populations. Gene expression profiles will be used to identify biological processes involved in physiological response to ingestion of Bt toxins. Markers developed for candidate loci associated with resistance to Bt toxins will be used to estimate allele frequencies in natural populations. Genetic loci under selection will be identified using statistical methods. A genetic linkage map of the bollworm developed using polymorphic markers will be used to study inheritance of loci of interest to Bt resistance.

**Summary:** A handful of genes associated with mechanisms conferring of tolerance to *Bacillus thuringiensis* (Bt) toxins in corn earworm and tobacco budworm have been identified. These genes include aminopeptidases, membrane-bound alkaline phosphatase, cadherins, and ABC transporters. Although the contribution of individual genes have been characterized to some extent, Bt toxin tolerance in these insects seems to involve interactions between multiple genetic loci. In order to perform genetic association studies on Bt tolerance, high-throughput genetic marker capture system was developed for corn earworm using genome sequences obtained from bacterial artificial chromosomes. Capture oligonucleotides were developed for approximately 3,900 markers and successfully used to identify markers from a test genome. Old-world cotton bollworm (*H. armigera*) has invaded Brazil and a few neighboring countries in South America. Due to climatic conditions optimal for development of this invasive pest in North America, it is an imminent threat to U.S. agriculture. A polymerase chain reaction-based assay capable of separating cotton bollworm, corn earworm, and tobacco budworm was developed and used to screen genomic DNA extracted from field collected insects. The assay is sensitive enough to identify corn earworm using a single partially developed egg. Over 1,500 insects collected from various locations in 2002, 2005, 2011, and 2013 have been screened. Insects collected in 2014 are currently being processed. *H. armigera* was not detected in this analysis. In addition, complete mitochondrial genomes of *H. virescens* and *H. zea* were sequenced for developing additional genetic markers for population studies. Polymorphic DNA

markers identified in the corn earworm were used to develop a preliminary genetic map by genotyping backcross families. A Bt toxin tolerant corn earworm strain is being used to conduct marker-based association studies to identify loci associated with Bt toxin tolerance. In addition, insects collected from field locations will be analyzed to determine the species identity.

Populations of *Helicoverpa zea* larvae were collected from multiple locations in Mississippi, Arkansas and Louisiana from crimson clover during 2013 and larvae were collected from some of the same locations during the spring of 2014. Larvae are being stored until further examination of the population genetics of the first spring generation can be examined. Initial screenings of lepidopteran pests of soybean, including the soybean looper, are being conducted to examine their current susceptibility to Cry toxins. This work is being conducted to examine current susceptibilities to those after the possible introduction of Bt soybeans in the U.S.

## 2014 Research Program Accomplishments

### Adams Research Program

An on-farm sweetpotato research study was completed at three locations near Mound Bayou, MS to evaluate the benefits of applying timely recommended applications of nematicides, insecticides and herbicides to control pest and increase yield. Treatments included Lorsban/K-Pam/Herbicide, Belay/K-Pam/Herbicide, K-Pam/Herbicide, Lorsban/Herbicide, Belay/Herbicide, Lorsban/No Herbicide, Belay/No Herbicide, K-Pam/No Herbicide and No Herbicide/No Insecticide. Treatments with insecticide, nematicide and herbicide applications, for the most part, were not significantly different from each other in Total Marketable yields, while yield in treatments without recommended herbicides were not significantly different from the No Herbicide/No Insecticide control treatment. Yield and quality were recorded and analyzed. Insect damage was recorded and analyzed and is presently being evaluated. **(L. Adams, C. Johnson)**

Continued collaborative research with Alcorn State University scientists studying sweetpotato insect identification, sampling and damage in the Mississippi Delta. USDA-ARS, SIMRU collaborated with ASU in a study to compare sweep net sampling and sticky trap sampling of insect populations in sweetpotato. The results of this study include experiments from 2007 to 2010 and should be submitted for publication in 2015. **(L. Adams, T. Rashid, C. Johnson)**

SIMRU annually participates in the National Sweetpotato Collaborators Group variety trials. Studies were conducted in 2014 at Mound Bayou, MS. SIMRU compared three LSU (L04-175, L06-052 & L07-146) and one NCSU (NC05-198) experimental varieties to three marketed varieties (Covington, Orleans & B94-14 Beauregard) at the ASU research farm in Mound Bayou, MS. The highest yielding varieties were the marketed Beauregard 94-14 and two experimental varieties L07-146 and L06-052. **(L. Adams, C. Johnson)**

Since 1992, SIMRU has monitored and reported populations of *H. zea* and *H. virescens* in the Mississippi Delta through pheromone trapping. In 2012 SIMRU moth trapping recorded a jump in *H. zea* moth captures from previous years since the introduction of transgenic crops. That trend continued during 2014 with an average number of moths per trap per week peaking at 111 in mid July. *H. virescens* captures remained relatively low throughout the season. **(L. Adams, C. Johnson)**

### Allen Research Program

Early-season wild hosts were sampled in the MS Delta to determine their importance in the build-up of stink bugs that are pests of soybean. Sampling for stink bugs began during the first week of April 2014. Stink bugs were collected from 10 different wild hosts. The most common stink bug collected was the brown stink bug, *Eushistus servus* found predominately on crimson clover, white clover, hairy vetch, daisy fleabane, and wild geranium. The first brown stink bug was collected April 10<sup>th</sup> in Warren County from crimson clover. The second most common stink bug was the green stink bug, *Chinavia hilaris*, and was collected from four different wild hosts. The first redbanded stink bug, *Piezodorus guildinii*, adult was collected from crimson clover on April 25<sup>th</sup> from the same location in Warren County. Most redbanded stink bugs collected have been from crimson clover, with a single adult collected from hairy vetch. The first redbanded stink bug nymph was also collected from crimson clover on May 15<sup>th</sup>. Four kudzu bug adults were collected from crimson clover while the majority of these insects were collected from kudzu. **(C. Allen, L. Andrews)**

The temporal and spatial distribution of stink bugs on soybean in the MS Delta was examined. Sampling for stink bugs in soybean began the first week of June. At least four locations were examined in Mississippi on a weekly basis and included fields in Warren, Issaquena, Washington and Sunflower Counties. The majority of stink bugs found early in soybean was the green stink bug. The only notable populations of kudzu bug during 2014 were found in Warren County, the most southern sample location, although at least one kudzu bug was found in soybean at all sampling sites. Redbanded stink bugs were more prevalent in Warren and Issaquena Counties, and numbers increased later in the season. Southern green stink bugs were encountered in the greatest numbers in the latest planting dates in Washington County. Brown stink bugs were present in low to moderate numbers in all sample locations. **(C. Allen, L. Andrews)**

Preliminary testing of kudzu bugs collected from Warren County, MS to two different insecticides, acephate and lambda-cyhalothrin, in adult vial tests were conducted. Survival at different concentrations and time intervals were examined. Technical grade insecticide was used to estimate lethal concentrations that killed 50% of the test population ( $LC_{50}$  values). The estimated  $LC_{50}$  value of kudzu bugs to acephate after an exposure time of 24 hours was less than 1 microgram per vial, while exposure of kudzu bugs to lambda-cyhalothrin resulted in an estimated  $LC_{50}$  of 0.07 micrograms per vial. Both of these estimates are lower than most published estimates for the common stink bug pest species found in soybean. **(C. Allen, L. Andrews)**

Action thresholds for stink bugs were examined on the USDA research farm in Washington County, MS. A maturity group IV variety, Asgrow 4632, and a maturity group V variety, Asgrow 5632 were planted in small plots and sampled weekly for numbers of stink bugs. Treatments included action threshold levels of 0, 3, 6, 9 and an untreated check for both varieties. Measurable numbers of stinkbugs were present for approximately 5 weeks during the study. For the Asgrow 4632 variety, the 0, 3, 6, and 9 action threshold levels were sprayed 5, 2, 1, and 1 times respectively. Yields for this variety ranged from 42.3 to 48.6 bushels/acre. The treatment with the highest numerical was the 0 threshold treatment. In the study examining action thresholds using Asgrow 5632, the 0, 3, 6, and 9 action threshold levels were sprayed 5, 2, 1, and 1 times respectively. Yields ranged from 37.2 to 43.2 bushels per acre. Seed samples from all treatments for both tests are being analyzed for damage due to stink bugs, oil, and protein content by Midsouth Grain Inspection Service, Memphis, TN. **(C. Allen, L. Andrews)**

### **Little Research Program**

We have been investigating new, innovative, and complimentary techniques to control corn earworms and tobacco budworms on cotton and corn. During the past year, we continued our investigations of different transgenic Bt and non-Bt cottons under sprayed and unsprayed conditions for their ability to control heliothines. Additionally, the benefits of supplementary control of heliothines with commercially available diamide formulations in transgenic cottons were also examined. These efforts included establishment of numerous sentinel plots, which served as a geographic representation of the Mississippi Delta farming region, and large field cage experiments to further our empirical knowledge of the effect of conventional and transgenic insecticides on heliothine ecology and phenology. In 2014, approximately 80% of non-Bt plots reached treatment threshold for bollworm, while only 20% of Bt cotton varieties were treated. Yield responses to diamide treatments for supplementary bollworm control varied by location, but some yield increases were evident in areas with high insect pressure. **(N. Little, C. Allen, R. Luttrell, and D. Adams)**

Heliothine larvae were collected from various plant tissues during different growth stages of cotton and corn in sentinel plots and large field cage experiments during the past summer. Laboratory analyses of bollworm non-binding site proteinases, such as esterases and glutathione-S-transferases, are being conducted on these larvae to quantify metabolic irregularities associated with feeding and survival on different Bt crop hosts. Ultimately, these larvae will give us insight into the genetic and physiological

changes associated with exposure to transgenic insecticides and their effect on survival in field environments. **(N. Little, and D. Adams)**

Combinations of microbial (viruses) and cultural controls (early vs late maturing varieties) were investigated to determine their feasibility as alternative control measures for heliothines in transgenic cotton. The effectiveness of various nuclear polyhedrosis viruses (NPVs) for corn earworm control were evaluated for their potential use in IPM programs for transgenic crops. NPVs were evaluated in sprayed and unsprayed field plots with early-mid and mid-late maturing cotton varieties. In general, bollworm larval densities were reduced by approximately 40-50% in plots sprayed with NPVs. These reductions were evident in both Bt and non-Bt cottons, and were reflected in yield increases across the study. **(N. Little, R. Luttrell, C. Allen, D. Adams)**

The economic benefits of growing transgenic Bt corn for control of corn earworms was evaluated in collaboration with scientists from other institutions. Bt and non-Bt events were examined for numbers of corn earworms and the resulting impacts on yield. Bt corn varieties with different trait packages suppressed the number of corn earworm larvae feeding on corn ears relative to their non-Bt isoline hybrids. However, no yield increases were observed for the Bt varieties over a non-Bt variety in a given hybrid line. **(N. Little and D. Adams)**

### **Luttrell Research Program**

Effective procedures to monitor changes in susceptibility of noctuid field populations to *Bacillus thuringiensis* derived proteins expressed in transgenic crops are lacking. Previous procedures, including many studies in SIMRU, have relied on the collection of feral insects and subsequent dose-response assays with test progeny reared under laboratory conditions. The assay procedures have typically been modifications of diet-incorporation and/or diet overlay procedures originally developed to screen formulations of different microbial insecticides. Efforts to address EPA mandated resistance monitoring relied on these adopted procedures to screen field populations collected from the geographic range of Bt crop deployment, and SIMRU played an important role in the early effort. We now need a different set of procedures to address a different question. We need to better understand if field populations are changing and what impact this may have on field control. Lab assays will be an important component of the work, but not the direct and major focus as was the case with the EPA mandated effort. We need procedures to index colony susceptibility so we can further quantify population changes in the field. With the original Bt crops based on single insecticidal toxins, assays were typically conducted with purified proteins provided by the biotech industry. This has become difficult because of limitations to the availability of the purified proteins and the expression of multiple insecticidal toxins in current Bt crops. To address these needs, we have been developing baseline information on the susceptibility of bollworm, tobacco budworm and fall armyworm to commercial Bt formulations (primarily Dipel and Javelin) and lyophilized Bt corn and Bt cotton tissues (TriplePro Corn, Bollgard II Cotton, and Widestrike Cotton). Studies with lyophilized tissue began in 2013 and continued in 2014. We have compared assay types (overlays vs. diet incorporation) and a number of different response variables. Using stunting (larvae failing to molt beyond 1<sup>st</sup> instar) as a component of the assays appears to be important to increase the effective dose challenging the test insects with lyophilized tissue. However, responses based on failure to molt to third instar do not appear to be useful because the control assays with non-Bt plant tissue also have a stunting effect. We have established strong baseline information for Dipel and Javelin with all of our laboratory studies. Experiments conducted in 2014 examined the susceptibility of seven field colonies of *H. zea* and two field colonies of *H. virescens*. Additional comparisons of lyophilized tissues and Dipel are planned, as well as a few direct comparisons to commercially purchased proteins. We are also investigating the possibility of producing reference proteins within SIMRU. **(R. Luttrell, N. Little, M. Mullen, C. Allen, O. P. Perera, Kenya Dixon, Maribel Portilla)**

SIMRU is devoted to the development of alternative insect control measures, especially those that are sustainable economically and are safe to the environment. Related research reports by Dr. Maribel Portilla and Dr. Nathan Little describe ongoing efforts to develop microbial control agents for tarnished plant bug and bollworm/tobacco budworm in cotton. This past year, we also began a study with AgBiTech to examine the efficacy of a NPV of fall armyworm. We compared a range of doses of the virus to field rates of Dipel and Belt in a spray-table assay with conventional and Bt corn and Bt cotton. Our laboratory colony of FAW was used as the assay insects. We conducted nine different experiments and demonstrated activity of the virus, but not levels comparable to the standard insecticide. Perhaps a more important aspect of the study was the experience we gained in working with the FAW virus and the improvements in our assays procedures. We intend to continue the studies this year, and actually expand the procedures to studies of other microbes and other noctuids in an effort to associate partial-life table impacts with observed insect control events in our field studies. (**R. Luttrell, M. Mullen, K. Dixon, A. Patterson, N. Little, O. Houston**)

Tarnished plant bug populations from the Delta Region of Mississippi and Arkansas were monitored for resistance to acephate, permethrin, imidacloprid, and thiamethoxam using procedures previously developed and used by Dr. Gordon Snodgrass. A related report by Dr. Katherine Parys describes a related and developing effort to develop resistance monitoring procedures for novaluron. A total of 56 different dose-mortality assays were conducted with acephate including 16 against SIMRU's laboratory colony and 40 field populations. The average LD50 based on treated scintillation vials was 31.2 ug per vial including projected LC50s for non-significant regression lines. Six of the 56 regression lines were non-significant with a range in LC50s from 10.3 to 621. Of the 50 significant dose-mortality regressions after 24 hr of exposure to acephate, LC50s ranged from 1.2 to 61.02 ug/vial. A total of 50 populations, including 12 assays with laboratory strains and 38 with field populations, were conducted with plant bugs exposed to permethrin in scintillation vials. Forty-eight dose-mortality regressions were obtained with 40 significant estimates of LC50 values. The average LC50 was 11.58 ug per vial with a range of 0.31 to 67.57 ug per vial. Using the diagnostic dose assay developed by Dr. Snodgrass (i.e. 3 hr mortality at 1.5 ug/vial), 21 of the 38 field populations would have been categorized as resistant to pyrethroid insecticides. Assays with thiamethoxam and imidacloprid were conducted using Snodgrass' floral foam methods. LC50s expressed as ug of thiamethoxam/ml of solution pipetted onto the foam averaged 3.61 for 14 assays with laboratory colonies and 3.83 for 34 significant regression lines measured for field populations. Variation in response was observed in some field populations. Dr. Jeff Gore with the Delta Research and Extension Center provided insects from a problem field, and Dr. Nathan Little later collected insects from a problem field in Coahoma County. The Coahoma County colony has a measured LD50 six-fold that of the average for laboratory assays (estimated at 18.01 ug/ml). The range in LC50s among significant dose-mortality regressions for field colonies was 0.38 to 14.58. Five field populations had high survival and non-significant regressions. With all insecticides, a few assays were conducted against late-season populations entering diapause. LD50s tended to be high for these populations regardless of the insecticide tested. (**R. Luttrell, K. Dixon, A. Patterson, M. Portilla, K. Parys, N. Little**)

### **Parys Research Program**

The introduction of transgenic crops containing Bt proteins has changed the quantity and type of pesticides applied in agricultural fields each year. Several new plant technologies are expected on the market in the next few years, including the possibilities of Bt soybeans and cotton plants expressing a gene for the control of *Lygus* spp. To monitor the potential impact of these new varieties on non-target organisms, we collected baseline data on arthropod community structure. Pitfall and flight intercept traps were used in both cotton and soybean fields to collect both ground and flying insects. (**K. Parys, N. Little, C. Roberts**)

The last host plant list available for *L. lineolaris* was published in 1986, over 25 years ago, and included 386 species. We continued to use online resources to compile an annotated list of host plant records in peer-

reviewed literature. Updated work puts the current total of published host plants at over 700 species across a broad phylogenetic range. **(K. Parys, G. Snodgrass)**

Recent research on pheromones for other *Lygus* species has revealed a blend that is potentially attractive to *L. lineolaris*. We screened these potential pheromone blends for attractiveness to field populations at four sites in Washington and Sunflower counties. Two of the five blends evaluated previously developed collected significantly more tarnished plant bugs than the other blends or a blank control. **(K. Parys, C. Roberts)**

Historical records of the appearance of the spring F1 generation of *L. lineolaris* in Washington County were examined for relationships between phenological stage of insects and a variety of predictive models of degree-day accumulation. Thirteen years of data was used to compare potential models, evaluate developmental thresholds, and select biofixes. Appearance of F1 adults in the early spring are best predicted using a sine wave model with a biofix of December 15<sup>th</sup> and a lower temperature threshold of 10°C (CV=13.93). This combination of parameters predicts the appearance of F1 adults at  $265 \pm 36.94$  degree days, and will be tested in future work. **(K. Parys, G. Snodgrass)**

Adult *L. lineolaris* were collected by sweeping and monitoring cotton at field two locations weekly. Additional information about pesticide application in field, phenological stage of cotton plants in the field, surrounding potential host plants, and weather information was recorded at each collection site and date. Insects collected were shipping to St. Louis, MO for analysis of host plant range and assessment of natural refuge. **(K. Parys, C. Roberts)**

Populations of *L. lineolaris* were collected from field locations, and returned to the lab to found colonies. Each of the individual colonies was reared on a meridic diet, and resulting eggs were removed. The F1 generation was reared on broccoli before being transferred onto meridic diet. During the 3rd instar, each population was evaluated for response to novaluron through a diet-incorporated bioassay. **(K. Parys, A. Patterson, K. Dixon, C. Roberts)**

### **Perera Research Program**

A few genes involved in the mode of action of *Bacillus thuringiensis* (Bt) toxins and mechanisms conferring of tolerance have been identified in corn earworm and tobacco budworm. These genes include aminopeptidases, membrane-bound alkaline phosphatase, cadherins, and ABC transporters and are considered as contributors of large effects to Bt toxin tolerance. It is hypothesized that there are a number of yet unknown genetic loci with small additive effects that also contribute to tolerance to Bt toxins. In order to understand involvement of interactions between multiple genetic loci and loci with small additive effects we have developed strategies to perform genetic association studies on Bt tolerance using genome re-sequencing, high-throughput genetic marker capture of genetic crosses between Cry1Ac tolerant and susceptible strains of corn earworm, *Helicoverpa zea*. **(O. Perera)**

Old-world cotton bollworm (*Helicoverpa armigera*) invaded Brazil in 2012 and has now spread to some of the neighboring countries in South America. Animal and Plant Health Inspection Service (APHIS) of USDA documented capture of *H. armigera* in Puerto Rico in September 2014. Due to climatic conditions optimal for development of this invasive pest in North America, it is an imminent threat to US agriculture. An assay based on polymerase chain reaction (PCR) amplification of mitochondrial DNA (mtDNA) capable of separating cotton bollworm, corn earworm, and tobacco budworm was developed and used to screen genomic DNA extracted from field collected insects. The assay is sensitive enough to identify corn earworm using a single partially developed egg. Over 1,000 insects collected from various locations in 2002, 2005, 2011, 2013, and 2014 have been screened. Insects collected Puerto Rico using *H. armigera*

pheromone lures are currently being analyzed using mtDNA and nuclear markers. Combined results are expected to identify *H. armigera*, *H. zea* and any hybrid insects. **(O. Perera, C. Allen, D. Jenkins (USDA-ARS, Mayaguez, PR), C. Pierce, P. Chatakondi)**

The perception and discrimination of odorants and other chemical cues in insects require odorant-binding proteins (OBPs) and chemosensory proteins (CSP). OBPs and CSPs bind chemical ligand and facilitate triggering of receptor combinations specific to the each class. We previously characterized and published the OBP repertoire of the tarnished plant bug, *Lygus lineolaris*. CSP repertoire of *L. lineolaris* and *L. hesperus* was identified using a transcriptomics-based. In total 12 putative CSPs were identified in each plant bug species. **(O. Perera, G. Snodgrass, C. Pierce, J. Hull -USDA-ARS, Maricopa, AZ)**

Complete mitochondrial genome of corn earworm, *H. zea* was characterized by sequencing and the processing of mitochondrial transcripts during embryonic development was studied using next-generation sequencing (RNA-Seq) of 2-hour zygotes and 48-hour old embryos. A manuscript of analysis was submitted to a peer reviewed journal. **(O. Perera, R. G. Luttrell, and T. Walsh -CSIRO, Australia)**

### **Portilla Research Program**

Five isolates of *Asperigillus flavus* (AF36, K49, K54, AFLygusField, AFLygusLab) including the Mississippi Delta native NI8 strain as a treated control were evaluated under laboratory conditions for pathogenicity and infectivity against tarnished plant bug. 6X10<sup>9</sup> concentration was used for all *A. flavus* strains and for *B.bassiana*. Mortality and infection on tarnished plant bug varied among strains of *A. flavus* and both were higher in Lygus treated with isolate K54. The pathogenicity test of K54 showed similar behavior when compared with NI8. Mortality of the treated adults was recorded after 3 to 5 days of exposure. Mycelial growth appeared 2 to 4 days after inoculation. However, *B. bassiana* had significant higher mortality and sporulation than *A. flavus* K54. These results suggested that *A. flavus* is a fungal pathogen that infects life stages of tarnished plant bug both in lab and field conditions. The fungus colonized, killed and produced spores on tarnished plant bug adult cadavers. From infected adult, the fungus was re-isolated and tarnished plant bugs were treated with different concentrations of K54. LC<sub>50</sub> and LD<sub>50</sub> for K54 were estimated. **(M. Portilla, H. Abbas, R. Luttrell and T. Ramsey)**

Diet overlay essays were conducted to evaluate the effect of six insecticides alone and in combination for mortality of tarnished plant bug by contact. 0.5 ml of each treatment was overlayed on solid Lygus diet cups. Each cup contained 3 g of solidified *Lygus* diet. Three groups of 30 adult mixed-sex, 0-D old, and three groups of 30 fifth instar nymphs were used per treatment. Each young adult and late nymph was individually placed into diet cups. Insects were held in an environmental room at 27°C, 65%RH, and 12L: 12D photoperiod. Insects were examined daily for five days for mortality. When exposed to artificial diet overlayed with the treatments Belay, Carbine, and Belay+Knack in the laboratory, tarnished plant bug nymphs experienced 100% mortality by contact 1 day after exposure (Day 1, p=0.056). Tarnished plant bug nymphs exposed to Acephate and Acephate+Karate also suffered high mortality after 1 day (85%), with the remainder perishing after 2 days of exposure (Day 2, p <.0001). Knack and Belay slowly increased mortality by Day 3 (p <.0001); however, 20% of the population survived the application (Day 5, p<.0001). No treatment has lower mortality than the control. Adult tarnished plant bug experienced 100% mortality after 3 hours when exposed to diet overlayed with Carbine or Karate+Acephate. Tarnished plant bug adults exposed to Belay experienced >50% mortality at 0 day following treatment; near 100% mortality was observed for this treatment after 4 days of exposure. There was <5% mortality observed for adults exposed to diet overlayed with either Knack, water, or the untreated control. In the diet overlayed with the IGR, Rimon, tarnished plant bug adult mortality never exceeded 50%. Significant differences among treatments

were observed for each time of evaluation when analyzed by ANOVA ( $p < 0.0001$  for hours 3, 5, 24, 48, 72, 96 and 120). (**M. Portilla, N. Little, C. Granadino, C. Solorzano, R. Luttrell and T. Ramsey**)

Laboratory assays were conducted to evaluate the effect of six insecticides alone and in combination for mortality of tarnished plant bug mortality by direct spray. Three groups of 30 adult mixed-sex 0-D old, and three groups of 30 fifth instar nymphal were used per treatment. Insects were sprayed with 6.0 ml of water (Control) and insecticide solution (treatments) (commercially labeled concentration 20 gl. / acre). All treatments were applied using a specially designed spray tower. After application, adults were released in an insect observation cage to let them dry and then transferred individually into solo cup with diet. Insects were held in an environmental room at 27°C, 65%RH, and 12L: 12D photoperiod and examined daily for five day for mortality. 100% mortality of tarnished plant bug nymphs were obtained at 1 day after sprayed with all treatments except for Knack, untreated and water control, which experienced no mortality and >2% mortality for Rimon, which reach 80% mortality after 5 days of exposure. No differences in mortality were observed between Knack, untreated and water control at day 4 and 5 post-application. Significant differences among treatments were observed for each time of evaluation when analyzed by ANOVA ( $p < 0.0001$  for hours 3, 5, 24, 48, 72, 96 and 120). Adult tarnished plant bug experienced 100% mortality after 3 hours after spray when exposed to diet with Belay or Karate+Acephate. Tarnished plant bug adults exposed to Carbine experienced >10% mortality at 0 day following treatment, increasing just to 20% at day 2 after spray; near 90% mortality was observed for this treatment after 5 days of exposure. There was <10% mortality observed for adults spray with Knack, which never when above 30%. No significant differences were found among Knack, water, or the untreated control at any evaluation time. Significant differences among treatments were observed for each time of evaluation when analyzed by ANOVA ( $p < 0.0001$  for hours 3, 5, 24, 48, 72, 96 and 120). (**M. Portilla, N. Little, C. Granadino, C. Solorzano, R. Luttrell and T. Ramsey**)

Field experiments were carried out to evaluate mortality of tarnished plant bug using different insecticides. Thirty-two plots, eight rows wide and 50' long (0.0306 acres) were planted with BGII cotton. Eight treatments were replicated four times. Treatments were randomized within each replication. Treatments were applied with a multi-boom research sprayer immediately following an initial plot insect assessment for TPB. Following the initial spraying, TPB assessments were made by employing 25 sweeps at 3, 7, and 14 days after treatment. The number of TPB adults and nymphs for each plot and rating were recorded. No broadcast applications of compounds for the control of TPB or any other insects were made during the duration of the test. Plots were harvested with a cotton-plot picker. The insect abundance data collected for this study were extremely variable and no significant differences could be found between treatments for this experiment. Although no differences could be found for insect densities among treatments, some differences were observed in cotton yields. These differences were analyzed based on 35% cotton lint gin-out with JMP8 software. Comparisons between treatment pairs were made using Student's t based on an ANOVA at  $\alpha = 0.05$ . No single treatment resulted in a higher lint yield than all others, but all treatments except for Knack resulted in a higher yield of cotton than the untreated control. There was no significant difference in cotton yield between Transform, Rimon, Carbine, and Belay+Knack; however, all were significantly higher than Knack alone and the untreated control. (**M. Portilla, N. Little, C. Granadino, C. Solorzano, R. Luttrell and T. Ramsey**)

The entomopathogenic fungus *B. bassiana* strain NI8 was evaluated for compatibility with two insect growth regulators under field condition. Sixteen plots were planted and maintained as described above (cotton variety, dimensions, time of applications, time of sampling, and tractor sprayer were the same). Each treatment (untreated control, NI8, NI8+Rimon, NI8+Knack) was replicated four times. Treatments were randomized within each replication and a plot of 4 rows of corn were planted between cotton plots to avoid contamination among treatments. Concentration of *B. bassiana* was  $6 \times 10^{12}$  spores / acre. All sprays included 1.5 ml of Tween-80 per gallon of spray. Insect assessment were made by employing four sets of ten sweeps per plot at 1 day before spray and 3, 7, and 14 days after treatment. The number of tarnished

plant bug adults and nymphs for each plot and rating were recorded. No broadcast applications of compounds for the control of TPB or any other insects were made during the duration of the test. No significant differences were found in lint yield between *B. bassiana*+Knack, *B. bassiana*, and control. Plots treated with the combination treatment *B. bassiana*+Rimon resulted in significantly higher yields than the other treatments. (M. Portilla, N. Little, C. Granadino, C. Solorzano, R. Luttrell and T. Ramsey)

The SIMRU Insect Rearing Group maintained production of 50,000 eggs per day for three species of Lepidopteran (*Helicoverpa zea*, *Heliothis virescens*, and *Spodoptera frugiperda*). Different stages of insect (eggs, larvae, pupae, and adults), mixed dry diet, and cupped diet were provided to several USDA scientists in order to complete their research projects. Over 20,000 first instar larvae of *H. zea* inoculated individually on diet solo cups were provided in 2014 for the USDA Future Scientist Program. Those insects were shipped for teaching purpose and distributed to thousands of school kids across the United States. (Henry Winters, Essanya Winder, M. Portilla, R. Luttrell, and Tabatha Nelson)

### **Zhu Research Program**

Potential multiple and cross resistance to Bt and organophosphate insecticides were examined in Puerto Rico population of the fall armyworm. Dose response assays showed that a fall armyworm (FAW) strain collected from Puerto Rico (PR) with 7717-fold Cry1F-resistance also developed 19-fold resistance to acephate. PR also evolved a deep (2.8%) molecular divergence in mitochondrial oxidase subunit II. Further examination of enzyme activities in the midgut of PR larvae exhibited substantial decreases of alkaline phosphatase (ALP), aminopeptidase (APN), 1-NA- and 2-NA-specific esterase, trypsin, and chymotrypsin activities, and significant increases of PNPA-specific esterase and glutathione S-transferase (GST) activities. When enzyme preparations from the whole larval body were examined, all three esterase, GST, trypsin, and chymotrypsin activities were significantly elevated in the PR strain, while ALP and APN activities were not significantly different from those of susceptible strain. Data indicated that multiple/cross resistances may have developed in the PR strain to both Bt toxins and conventional insecticides. Consistently reduced ALP provided evidence to support an ALP-mediated Bt resistance mechanism. Esterases and GSTs may be associated with acephate resistance through elevated metabolic detoxification. (Y.C. Zhu, C. Blanco, M. Portilla, J. Adamczyk, R. Luttrell and F. Huang)

Acute toxicity bioassays were conducted on European honeybees. A total of 25 dose-response assays were conducted to optimize an acute toxicity assay method developed in late 2013, and 142 dose-response assays were conducted in 2014. In 2014, 42 pesticides, including one fungicide and one herbicide, were tested for their spray toxicity against honey bees using modified spray tower. Results indicated that at recommended field application rates, 21 insecticides may kill 99% or more worker bees, including dicotophos, emamectin benzoate, clothianidin, abamectin, acephate, thiamethoxam, a few carbamates and pyrethroids, and sulfoxaflor. Six chemicals may kill less than 1% worker bees, including acetamiprid, chlorantraniliprole, etoxazole (miticide), tetraconazole (fungicide), and glyphosate (herbicide). The remainder of the 15 chemicals killed 1-99% bees at field application rates. This study provided clear and realistic scale for measuring the acute toxicity of foliar spray. The information is valuable for guiding insecticide selection to minimize direct killing of foraging bees and to maintain effective control of field crop insects as well. (Y.C. Zhu and J. Adamczyk)

Sub-lethal dose toxicity with insecticides exposed to European honey bee studies were conducted. Workers bees were subjected to sub-lethal dose treatments of thiamethoxam (at 0.5, 1, and 2 mg/L), acephate (at 0.14, 1.4, and 14 mg/L), clothianidin (at 15 and 20 mg/L), and dicotophos (at 9 and 11 mg/L). The bees (4x200) were sprayed twice a week (Mon and Thu) and bee samples were collected twice a week (Tue and Fri) until all bees died (up to 44 days). Mortality data were collected before each spray and each sampling. Treated bees are currently in processing for analysis of esterase, glutathione S-transferase, and other

defense-related enzyme activities. Preliminary data showed that bees, frequently treated with sub-lethal dose of clothianidin and dicotophos, died 6-10 days sooner than bees treated with water.  
**(Y.C. Zhu and J. Adamczyk)**

## 2015 Research Plans

### Adams Research Plans

In 2015, SIMRU will continue on-farm research to study insecticide control of wireworm, white grub and lepidopteran pest in sweetpotato. During 2014 Mississippi sweetpotato growers experienced very high populations of armyworms in isolated fields that required insecticide applications for control. SIMRU will evaluate several new insecticides for armyworm control in sweetpotato during the 2015 growing season. **(L. Adams, C. Johnson)**

SIMRU will continue collaborative research with Alcorn State University scientists studying sweetpotato insect identification, sampling and damage in the Mississippi Delta in 2015. **(L. Adams, C. Johnson)**

The twenty-third year effort to monitor and report populations of *H. zea* and *H. virescens* in the Mississippi Delta through pheromone trapping will be continued at the same sample-sites. Weekly data will be provided to the Mississippi Cooperative Extension Service to alert farmers to pest threats. **(L. Adams, C. Johnson)**

### Allen Research Plans

The spatial and temporal distribution of various stink bug and lepidopteran species in the MS Delta will continue to be examined. **(C. Allen, L. Andrews)**

The species composition of bollworm and tobacco budworms in early and late planted soybeans in the MS Delta will be examined. **(C. Allen, L. Andrews)**

An evaluation of sprayed and unsprayed plots for lepidopteran pests in early and late planted soybean and cotton at different levels of infestation and the subsequent impact on yield within production fields will be conducted. **(C. Allen, L. Andrews, N. Little, D. Adams, R. Luttrell)**

### Little Research Plans

Sentinel plot and large field cage evaluations of pyramided-gene Bt cottons under sprayed and unsprayed conditions for their ability to control heliothines will continue. Field performance data from these experiments will be correlated with results from laboratory and plant-based assays. **(N. Little, C. Allen, R. Luttrell, and D. Adams)**

Screenings for physiological changes in heliothines associated with exposure to conventional and transgenic insecticides and their effect on survival in field environments will be continued. **(N. Little, and D. Adams)**

Evaluations of microbial insecticides (NPVs) will continue in conventional and transgenic cottons using a conventional and a system sensitive approach with regard to preserving beneficial insects. This approach may allow us to reap the benefits of a natural, undisturbed system for the control of heliothines. **(N. Little, R. Luttrell, C. Allen, D. Adams)**

Economic evaluations of Bt trait packages in corn for the control of corn earworms will be expanded to include numerous sentinel locations throughout the MS Delta. **(N. Little and D. Adams)**

## **Luttrell Research Plans**

In 2015, efforts will continue to develop a bioassay laboratory to routinely conduct diet incorporation, diet overlay and topic bioassays of noctuid larvae exposed to biological toxins, microbial and chemical insecticides. We are also considering a renewed emphasis on spray-table assays. The purpose of the laboratory will be to provide quantitative assays for resistance monitoring, collaboration of field efficacy measurements and investigation of new biocides. An important component is expanded capacity to rear and test feral populations. Plans are underway to renovate existing SIMRU space to house large numbers of noctuid populations. Ideally, this will facilitate population genetics studies and provide a wide-range of different population traits for subsequent experiments and genetic studies. A focus of the work will be experiments to link the population variability to field control projects in the field and in large cages. Dr. Maribel Portilla will join the project to provide additional expertise in insect rearing and preservation of the field genetic traits in colonized populations. Expansion of assays with chemical insects is anticipated in 2015. **(R. Luttrell, M. Mullen, N. Little, M. Portilla, O.P. Perera, Clint Allen)**

Monitoring of tarnished plant bug populations will continue and expand in 2015. Field populations collected in a team project with Dr. Maribel Portilla and Dr. Katherine Parys to quantify tarnished plant bug population dynamics on different hosts will be assayed for susceptibility to acephate, permethrin, thiamethoxam, and possibly novaluron and sulfoxafur. Procedures will be those used in 2014 and modifications of the Snodgrass methods. New procedures are being developed for novaluron and sulfoxafur. **(R. Luttrell, M. Portilla, K. Parys, A. Patterson, K. Dixon)**

In collaboration with Dr. Maribel Portilla and Dr. Katherine Parys, field studies will be conducted to measure the impact of sprays of *Beauveria bassiana* on tarnished plant bugs and associated arthropods in wild hosts and agronomic crops. Efforts in 2015 will focus on identification of targeted study sites for early-season hosts in 2016, and initiation of sprayed observations on tasseling corn and perhaps early-season soybean. **(R. Luttrell, K. Parys, M. Portilla, N. Little)**

## **Parys Research Plans**

A large sampling effort with collaborators across the southeast will be made to match phenological stages of *L. lineolaris* with the best predictive models of degree day accumulation from data previously collected locally in Washington County. **(K. Parys, M. Portilla, N. Little, K.C. Allen)**

We will sample overwintering populations of *L. lineolaris* on senescing vegetation and in leaf litter to determine the proportion of adults overwintering in each habitat type. **(K. Parys, C. Roberts)**

Evaluating the usefulness of potential pheromone blends for trapping and monitoring efforts will focus on trap designs, pheromone blends, and deployment strategies for optimized use. **(K. Parys, C. Roberts)**

Adult *L. lineolaris* will be collected from cotton fields and subjected to stable carbon isotope analysis, and analyzed using the R package SCIAR to determine what mix of host plants the insects have fed on. **(K. Parys, C. Roberts)**

## **Perera Research Plans**

High-throughput genome re-sequencing of *H. zea* and *H. armigera* is planned for conducting genome-wide association studies (GWAS) and genome best linear unbiased prediction (gBLUP) to identify genetic loci contributing to insecticide and Bt toxin tolerance. **(O. Perera and Z. Abdo -USDA-ARS, Athens, GA)**

Using bioinformatics we have developed 384 single nucleotide polymorphism (SNP) markers for corn earworm, *H. zea*. These markers are currently being validated using field collected corn earworm DNA samples. We plan to test validated markers on *H. armigera* genomic DNA to evaluate the possibility of using these markers to identify genetic hybrids of *H. zea* and *H. armigera*. Population genetics studies of *H. zea* collected from several field locations in the south are planned. (**O. Perera, D. Jenkins (USDA-ARS, Mayaguez, PR), C. Allen, N. Little**)

### **Portilla Research Plans**

Preliminary laboratory studies will be conducted in order to obtain life tables and growth rates estimations for TPB from the field. (**M. Portilla, R. Luttrell, and T. Nelson**)

Possible new microbial control agent will be isolated from *L. lineolaris* collected from field and will be bioassayed to evaluate pathogenetic action on TPB adults. Bioassays will be conducted to evaluate the virulence and compare them with NI8. LC<sub>50</sub>s and LD<sub>50</sub>s will be estimated. (**M. Portilla, K. Parys, R. Luttrell, and T. Nelson**)

LC<sub>50</sub> values for insecticides against TPB lab colonies will be estimated using overlaid diet bioassays and direct spray. (**M. Portilla, N. Little, R. Luttrell and T. Nelson**)

The SIMRU Insect Rearing Group will continue its production in order to provide material for researchers and for the Future Scientist Program. (**Henry Winters, Essanya Winder, M. Portilla, R. Luttrell, and Tabatha Nelson**)

### **Zhu Research Plans**

Synergistic/antagonistic interactions of different pesticides on honey bees will be accessed in 2015. Insecticide studies will include major risk concerning insecticides (such as imidacloprid, clothinidin, and thiamethoxam), widely/heavily used insecticides (such as acephate), widely used insecticides for corn rootworm control (such as chlorpyrifos, beta-cyfluthrin, and bifenthrin), and representative (commonly used) insecticides from different insecticide classes. All will be examined for their interaction and synergistic/antagonistic toxicity with miticides (amitraz and thymol), nosema treatments (fumigillin), herbicide (glyphosate), and soybean fungicides (fluoastoxin, and tetraconazole). The synergistic toxicity will also be examined between insecticide classes/formulations, including many novel insecticides. To simulate tank mix interactions, major insecticides at LC30 concentration will pairwise examined with miticides, herbicides, and fungicides to reveal their possible synergistic/antagonistic toxicity against honey bees. Spray tower applications will be used to treat caged bees with two chemicals, individually and together, at LC30-concentration. Mortality will be recorded 2 days or longer (for slow acting insecticides) after treatment. (**Y.C. Zhu, J. Yao, J. Adamczyk**)

Sublethal toxicity/impact of commonly used pesticides on honey bee physiology and health will be assessed in 2015. Exposure to sublethal doses of toxic chemicals may have negative impact on honey bee physiology. Long term exposure may prompt selection and temporarily or permanently alter genetic structure and gene expressions in selected populations. To examine sub-lethal toxicity of major commonly used insecticides, young bees (~200 bees per rep) at 1-2 days old will be challenged (spray) twice a week with insecticides (imidacloprid or thiamethoxam or clothianidin) at 1 mg/L and LC<sub>1</sub> concentrations. A water only spray will be used as control. One day after each treatment, 32 surviving bees will be collected and stored in -80C freezer. Insecticide treatment and sample collection will continue for 6-8 weeks or until all bees die. Dead bees will be counted and removed before each

sampling. All samples will be subjected to enzyme (defense-, immunity-, metabolic-related) activity assay and/or real-time analysis of relevant genes. **(Y.C. Zhu, J. Yao, J. Adamczyk)**

## 2014 Trust Fund or Reimbursable Cooperative Agreements

**Project Title:** Variability in Host Use by Soybean Pests: Field Collections of *Helicoverpa zea* *Heliothis virescent* and *Chrysodeixis includens*

**Agreement No.:** 58-6402-3-037T

**ARS Investigator:** Clint Allen

**Project State Date:** 7/1/2013

**Project Funded By:** Monsanto

**Project Investigator:** Samuel Martinell

**Project End Date:** 6/30/2018

### 2014 Accomplishments:

Pheromone traps were established in three Mississippi Counties: Coahoma, Leflore, and Washington Counties during the 2013 and 2014 growing seasons. At each location, six traps were placed at the interface of a field of Bt cotton and soybean. Traps were baited with synthetic pheromone of three different moth species: corn earworm, *Helicoverpa zea*, tobacco budworm, *Heliothis virescens*, and soybean looper, *Chrysodeixis includens* (two traps for each species). Moths were collected on a weekly basis from all locations, moths that were in good shape were placed individually into vials and shipped to Monsanto where they are being analyzed to determine host of larval development. Overall, moth trap captures during 2014 were lower than those collected during 2013, especially so for soybean looper moth trap captures. Drop cloths samples in both the Bt cotton and soybean fields adjacent to pheromone traps were conducted and the number of larvae of each species collected were recorded. During 2013, the only significant number of larvae found in drop cloth samples was in the field of soybean located at the Coahoma County location and the majority of these were corn earworm. During 2014, the only noted caterpillars collected in drop cloth samples were soybean loopers found in soybean in Leflore and Coahoma counties.

### 2015 Research Plans:

Plans are pending.

**Project Title:** Biology of and Management Strategies for Redbanded Stink Bug, an Emerging Threat to US Soybean Production

**Agreement No.:** 58-6402-4-022R

**ARS Investigator:** Clint Allen

**Project State Date:** 1/1/2014

**Project Funded By:** LSU AgCenter

**Project Investigator:** Jeff Davis

**Project End Date:** 12/31/2016

#### **2014 Accomplishments:**

The regional and alternate hosts of redbanded stink bugs were examined in Louisiana, Mississippi and Texas during 2014. Stink bugs were sampled when daily mean temperatures exceeded 15°C. Various species of clover (red and white) appear to be the most important spring hosts in the build-up of redbanded stink bug populations, but hosts utilized between clover and the movement into soybeans need further examination. In soybean, regional populations of redbanded stink bug are lower than peak populations that were observed during the 2010 season, when they were the predominant stink bug species found in some fields in the upper MS Delta. Insecticide susceptibilities of redbanded stink bugs were examined in adult vial tests with technical grade insecticides to monitor their susceptibilities to commonly used pyrethroid and organophosphate insecticides. A regional effort to examine currently recommended action thresholds for stink bugs based on soybean seed yield and quality was conducted. In Mississippi, minimal differences were observed between a range of treatment levels in resulting yield or seed quality. USDA soybean accessions were examined for tolerance to RBSB under laboratory and field conditions. Also, spinosad was examined in preliminary field trials to determine the possibility of attracting redbanded stink bugs to this compound along field edges where it could slow colonization into the field.

#### **2015 Research Plans:**

The same studies will be conducted for a second year in 2015.

**Project Title:** Joint Action of Chemical Insecticides, Insect Growth Regulators and *Beauveria bassiana* to Control Tarnished Plant Bugs in Cotton

**Agreement No.:** 58-6402-4-040T  
**ARS Investigator:** Maribel Portilla

**Project Funded By:** Valent USA Corp.  
**Project Investigator:** Cesar D Solorzano  
Torres

**Project State Date:** 7/1/2014

**Project End Date:** 7/1/2015

#### **2014 Accomplishments:**

Field experiments were carried to evaluate mortality of TPB using different insecticides. Thirty-two plots, eight rows wide and 50' long (0.0306 acres) were planted with BGII cotton. Eight treatments were replicated four times. Treatments were randomized within each replication. Treatments were applied with a multi-boom research sprayer immediately following an initial plot insect assessment for TPB. Following the initial spraying, TPB assessments were made by employing 25 sweeps at 3, 7, and 14 days after treatment. The number of TPB adults and nymphs for each plot and rating were recorded. No broadcast applications of compounds for the control of TPB or any other insects were made during the duration of the test. Plots were harvested with a cotton plot picker. The insect abundance data collected for this study was extremely variable and no significant differences could be found between treatments for this experiment. Although no differences could be found for insect densities among treatments, some differences were observed in cotton yields. These differences were analyzed based on 35% cotton lint gin-out with JMP8 software. Comparisons between treatment pairs were made using Student's t based on an ANOVA at  $\alpha=0.05$ . No single treatment resulted in a higher lint yield than all others, but all treatments except for Knack resulted in a higher yield of cotton than the untreated control. There was no significant difference in cotton yield between Transform, Rimon, Carbine, and Belay+Knack; however, all were significantly higher than Knack alone and the untreated control.

The entomopathogenic fungus *B. bassiana* strain NI8 was evaluated for compatibility with two insect growth regulators under field condition. Sixteen plots were planted and maintained as described above (cotton variety, dimensions, time of applications, time of sampling, and tractor sprayer were the same). Each treatment (Untreated control, NI8, NI8+Rimon, NI8+Knack) was replicated four times. Treatments were randomized within each replication and a plot of 4 rows of corn were planted between cotton plots to avoid contamination among treatments. Concentration of *B. bassiana* was  $6 \times 10^{12}$  (spores / acre). All sprays included 1.5 ml of Tween-80 per gallon of spray. Insect assessment were made by employing four sets of ten sweeps per plot at 1 day before spray and 3, 7, and 14 days after treatment. The number of TPB adults and nymphs for each plot and rating were recorded. No broadcast applications of compounds for the control of TPB or any other insects were made during the duration of the test. No significant differences were found in lint yield between *B. bassiana*+Knack, *B. bassiana*, and Control. Plots treated with the combination treatment *B. bassiana*+Rimon resulted in significantly higher yields than the other treatments.

#### **2015 Research Plans:**

Measure mortality of immature population of tarnished plant bugs in bioassays for Knack vs. Belay.

**Project Title:** Baseline Susceptibility of Tarnished Plant Bug to the Insect Growth Regulator, Novaluron

**Agreement No.:** 58-6402-0-531T

**Project Funded By:** Makhteshim-Agan of North  
America

**ARS Investigator:** Katherine Parys

**Project Investigator:** James Whitehead

**Project State Date:** 9/1/2010

**Project End Date:** 8/30/2015

**2014 Accomplishments:**

Novaluron is a relatively new insecticide used to control insects in cotton fields across the Mississippi Delta. Populations of adult tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois), were collected from field locations brought to the lab to found colonies. Each of the individual colonies was reared on a meridic diet, and resulting eggs were removed. The F1 generation was reared on broccoli before being transferred onto meridic diet. During the 3rd instar, each population was evaluated for response to novaluron through a diet incorporated assay.

**2015 Research Plans:**

This research agreement concludes in 2015. Data are being processed for a manuscript on the baseline levels of tolerance to novaluron in *Lygus lineolaris*.

**Project Title:** Assessment of Natural Refuge for *Lygus lineolaris*

**Agreement No.:** 58-6402-3-041T  
**ARS Investigator:** Katherine Parys  
**Project State Date:** 8/1/2014

**Project Funded By:** Monsanto  
**Project Investigator:** Doug Sumerford  
**Project End Date:** 7/31/2019

**2014 Accomplishments:**

Adult *L. lineolaris* were collected by sweeping and monitoring cotton at two locations weekly. Additional information about pesticide application in field, phenological stage of cotton plants in the field, surrounding potential host plants, and weather information was recorded at each collection site and date. Insects collected were shipping to St. Louis, MO for analysis and assessment of natural refuge.

**2015 Research Plans:**

Plans have not been made for the 2015 season.

## 2014 Specific Cooperative Agreement Research Accomplishments

**Project Title:** Low input systems of pest control for sweetpotato in the Mississippi Delta

**Alcorn State University**

**Project Investigator:** Tahir Rashid

**Project State Date:** 8/1/2011

**Agreement No.:** 58-6402-1-614

**ARS Investigator:** Randall Luttrell

**Project End Date:** 8/31/2014

### 2014 Accomplishments:

#### Comparison of yield and insect damage to organic sweetpotatoes

Organic sweetpotato varieties consisting of Beauregard, All Purple, Porto Rico and O'Henry were hand transplanted in randomized complete block design in replicated research plots in ASU Extension/Research Demonstration Farm and Technology Transfer Center, Mound Bayou, MS. Each plot had 2 rows and contained 20 sweetpotato plants on conventional raised beds with 0.5 m distance between plants and 1.0 m between rows. Drip irrigation was used as needed until the plants were established. Weed control within and around the plots was accomplished by hoeing and gas powered push tiller. All treatment plots were harvested at maturity. Prior to harvest sweetpotato vines were collected from one row (10 plants) of each plot and weighed. Twenty-five random sweetpotato root samples were evaluated for yield and insect damage. Roots were differentiated into jumbo grade, US No. 1 and canners. Insect damage to roots was determined by specific feeding marks of white grubs, wireworms, 12-spotted cucumber beetle, sugarcane beetle and flea beetles. Roots damaged by more than one insect were categorized as multiple insect-damage. Overall insect damage significantly differed among different varieties. All Purple had the lowest damage compared to others. Similar trend was observed with white grub-feeding damage, whereas, wireworm-feeding holes were significantly more in Beauregard and All Purple and none in O'Henry and Porto Rico. Flea beetle, sugarcane beetle and 12-spotted cucumber beetle damage did not differ significantly among different varieties. Porto Rico and O'Henry had significantly higher multiple insect feeding damage than other varieties. Weight measurement of sweetpotato vines indicated no significant difference in vegetative growth among different varieties evaluated in this study. O'Henry had significantly higher net yield weight than other varieties. Results of this experiment suggest likelihood that some organic sweetpotato varieties may be adaptable to local environment.

#### Survey of wireworm larvae and adults in experimental and private sweetpotato fields

Soil bait traps containing steamed crimped oats soaked overnight were installed in commercial and research sweetpotato fields to collect wireworm larvae. Each treatment bait was dispensed in a 6.5 cm diameter and 13 cm deep hole made with a bulb planter. The bait grains inside each hole were covered with soil and encircled with a 15 cm diameter and 15 cm long PVC pipe painted orange for later retrieval. Each sampling area consisted of 4 rows X 45 m. with four sampling points. One soil trap was installed at each sampling point. Each of two locations had 16 soil bait traps in four sampling areas. The samples were collected weekly by digging each trap site and brought back to the laboratory for counting and identification. At both locations weekly counts of wireworm larvae (*Conoderus vespertinus*) were very low.

Purple sticky traps for wireworm adult collection: Adult wireworm population was monitored by sticky traps constructed with 76.2 cm x 25.4 cm purple corrugated sheets attached to 1.2 m wood stakes. Four purple sticky traps were installed at each of two locations. Traps were replaced weekly, insects collected

and identified to species. Consistent numbers of adult wireworms (*C. vespertinus*) were collected on these traps.

### **2015 Research Plans:**

Sweetpotato Variety Test: Organic sweetpotato varieties tested during 2014 will be compared with conventional varieties in similar environmental conditions. Both organic and conventional research plots will be established in ASU Extension/Research Demonstration Farm and Technology Transfer Center, Mound Bayou, MS. Sweetpotato samples will be harvested at maturity, insect damage and net yield of the sweetpotato roots will be compared.

Insect Pest Monitoring: Insect pests will be monitored in sweetpotato research plots. Both larvae and adult wireworms will be sampled throughout the season in soil bait traps and purple sticky traps, respectively.

Live adult and larval wireworm collection: Soil bait traps containing corn and/or steamed crimped oats and installed at variable depths will be compared for attraction to wireworm larvae. Multifunnel traps constructed with purple sheets will be installed in and around sweetpotato research and commercial fields to collect live adult click beetles.

Insecticide Bioassays: Efficacy of different insecticides will be evaluated against wireworms subject to collection of sufficient numbers of larvae and/or adults in soil bait traps or purple multifunnel traps, respectively.

### **Working manuscripts**

The following manuscripts will be submitted for publication in peer-reviewed journals:

Title: Comparison of different sampling methods for insect pests in sweetpotatoes

Authors: T. Rashid, R. Luttrell, C. Abel, P. McLeod and L. Adams

Title: Effect of sweetpotato variety and cultural practices on insect damage

Authors: T. Rashid, C. Abel, R. Luttrell, P. McLeod and L. Adams

Title: Effect of Prohexadione-Ca on yield and insect damage to sweetpotatoes

Authors: T. Rashid, V. Njiti, R. Luttrell, P. McLeod and L. Adams

**Project Title:** Transgenic crop efficacy against target pests in agronomic crops

**Mississippi State University**

**Project State Date:** 08/01/2013

**Project Investigator:** Jeff Gore

**Agreement No.:** 58-6402-3-039

**Project End Date:** 08/01/2018

**ARS Investigator:** Randall Luttrell

## **2014 Accomplishments:**

**Approach:** Several studies were conducted during 2014 to evaluate the performance of transgenic Bt technologies in field corn and cotton. One project (Study 1) included plantings of non-Bt corn and corn expressing the Genuity VT Double Pro technology (Cry1A.105 + Cry2Ab2). Non-replicated strips were planted at ca. two weeks intervals beginning in early April at the Delta Research & Extension Center, Stoneville, MS. The planting dates included 2 Apr, 16 Apr, 1 May, 19 May, and 18 Jun. When plants were at the milk stage, 100 ears from each hybrid were examined for corn earworm larvae. Larvae were categorized as small, medium, or large in size. The sample dates included 23 Jun, 30 Jun, 7 Jul, 25 Jul, and 22 Aug.

Another study was conducted at three locations in Mississippi (Study 2). Two trials were planted at each location, one during the early part of the planting window and another at the end of the recommended planting window. Hybrids representing the most common Bt technologies (Genuity VT Double Pro®, Herculex®, Optimum® Leptra™) were compared to non-Bt hybrids from the same hybrid family. Trials were monitored for infestations of Southwestern corn borer, corn earworm, and fall armyworm. Corn earworm/fall armyworm densities were determined by sampling 10 ears per plot at the milk stage. Larvae were categorized as small, medium, or large. Yields were determined and an economic analysis was conducted. The locations included the Delta Research & Extension Center, Stoneville, MS, the R. R. Foil Research Farm, Starkville, MS, and an experimental field site south of Leland, MS. At all locations treatments were replicated four times in a randomized complete block design.

A third study was conducted to investigate the field performance of commercial Bt cotton genotypes against lepidopteran pests. Plots of non-Bt cotton (DP 174RF), Bollgard II (STN 5288 B2RF), Widestrike (PHY 499 B2RF), TwinLink (STN 5289 GLT), and Widestrike 3 (PHY 495 W3RF) were planted in a split-plot arrangement at the Delta Research and Extension Center in Stoneville, MS. The main-plot factor was spray treatment and included sprayed with chlorantraniliprole or unsprayed. The subplot factor included variety and consisted of the varieties previously listed. Plots were scouted weekly and the numbers of damaged terminals, squares, and bolls were recorded. At the end of the season, all plots were harvested and lint yield per acre was determined.

**Results:** In Study 1 there were no significant differences in small larvae between the non-Bt and VT Double Pro hybrids. The VT Double Pro hybrid had significantly lower densities of medium, large, and total corn earworm larvae compared to the non-Bt hybrid.

In Study 2 for the early planted trials there were no significant differences between the non-Bt and Genuity VT Triple Pro hybrids for numbers of small corn earworm larvae. The Optimum Leptra hybrid had significantly fewer small corn earworm larvae compared to the non-Bt and Herculex hybrids. Plots planted to the Genuity VT Triple Pro hybrid had significantly fewer medium, large, and total larvae compared to the non-Bt hybrid. Also the Optimum Leptra hybrid had significantly fewer medium, large and total corn earworm larvae compared to the non-Bt and Herculex hybrids. There were no significant differences in damaged kernels between the Genuity VT Triple Pro and non-Bt hybrids. The Optimum Leptra hybrid had significantly lower kernel damage compared to the non-Bt and Herculex hybrids. There were no significant differences in yield between the Genuity VT Triple Pro and non-Bt hybrids or between the Optimum Leptra, Herculex, and non-Bt hybrids.

For the late planted trials there were no significant differences between the non-Bt and Genuity VT Triple Pro hybrids for numbers of small corn earworm larvae. The Optimum Leptra hybrid had significantly fewer small corn earworm larvae compared to the non-Bt and Herculex hybrids. Plots planted to the Genuity VT Triple Pro hybrid had significantly fewer medium, large, and total larvae compared to the non-Bt hybrid. The Optimum Leptra hybrid had significantly fewer medium, and large corn earworm larvae compared to the non-Bt hybrids. Also, the Optimum Leptra hybrid had significantly fewer total corn earworm larvae compared to the Herculex and non-Bt hybrids. The Genuity VT Triple Pro hybrid had significantly fewer damaged kernels compared to the non-Bt hybrid. The Optimum Leptra hybrid had significantly lower kernel damage compared to the non-Bt and Herculex hybrids. There were no significant differences in yield between the Genuity VT Triple Pro and non-Bt hybrids or between the Optimum Leptra, Herculex, and non-Bt hybrids.

For the third trial, significant differences were observed in terminal, square, and boll injury among varieties and spray treatments. In general, square injury was significantly lower in the sprayed plots compared to the unsprayed plots for all technologies except Bollgard II and Widestrike 3. Significant levels of square injury were observed in the unsprayed plots of all technologies at multiple sampling times. Square injury in the unsprayed plots ranged from 38% to 66% in the non-Bt cotton. In contrast, square injury ranged from 19% to 35%, 7% to 11.5%, 1% to 5%, and 11% to 17.5% in Widestrike, Widestrike 3, Bollgard II, and TwinLink cottons, respectively. Overall, boll injury was less common than square injury, but trends were similar. Boll injury ranged from 4.5% to 13.0% in the unsprayed non-Bt cotton. Yields from the sprayed plots were significantly greater than yields from the unsprayed plots for all technologies. Heliothine populations in 2014 consisted of mostly bollworm, *Helicoverpa zea*.

**Summary:** Populations of bollworm at the DREC can be classified as moderate to very high in 2014. As a result, significant levels of larval infestation and feeding were observed in all Bt technologies in both corn and cotton. Although all of the technologies performed as expected, the presence of bollworms surviving in and damaging Bt crops should be closely monitored. Specifically, the presence of 2-4 day old larvae surviving and feeding near the terminal of Bt cotton plants was not accurately captured in these trials. Historically, this type of feeding has been common in Widestrike cotton because of the promotor used in combination with the Bt genes. However, survival in the terminal of Bollgard II (and the original Bollgard) cotton was considered rare until recent years. Additionally, the new Bt cotton technology that expresses a vegetative insecticidal protein (Vip, Widestrike 3) was commercially grown for the first time in 2014. This technology performed significantly better than the original Widestrike technology. However, significantly more square injury was observed in Widestrike 3 than in Bollgard II cotton. This suggests that, although new technologies may provide significant benefits from a resistance management standpoint, they provide little additional value to growers from a management standpoint.

### **2015 Research Plans:**

Research conducted in 2014 will be continued in 2015.

**Project Title:** Transgenic crop efficacy against target pests in agronomic crops

**Mississippi State University**

**Project State Date:** 08/01/2013

**Project Investigator:** Fred Musser

**Agreement No.:** 58-6402-3-038

**Project End Date:** 08/01/2018

**ARS Investigator:** Clint Allen

## **2014 Accomplishments:**

### **Cotton**

**Methods:** Bollgard II cotton (DP 132 B2RF) was planted beside non-Bt cotton (DP 174 RF) on 3 different planting dates (May 12, June 6 and June 18, 2014) in Starkville, MS. Plots were at least 8 rows wide and 200 ft long. The cotton was grown using typical agronomic practices. No insecticides were applied to the cotton. At harvest, 10 row ft of cotton was hand harvested from each of two sections of each variety for each of the first two planting dates. Harvested sections were parallel to each other and each harvested section was treated as a replicate. Three sections of each variety were harvested from the third planting date. Lint per acre was estimated assuming a lint turnout of 40%.

**Results:** Yield was consistently numerically higher in the Bt fields than the non-Bt fields, but was not statistically different (Table 1). However, the percentage of bolls showing insect damage, and consequently the percentage of bolls looking good was significantly different. The percentage of aborted bolls was not significantly different, as this parameter was apparently largely determined by agronomic conditions this year.

Table 1. Harvest data from 2014 Bt- non-Bt cotton comparison, Starkville, MS

Planting Date	Treatment	Yield (lb lint/ac)	# Boll Positions	% Good Bolls	% Damaged Bolls	% Missing Bolls
12-May	Bt	1403 ± 55	115 ± 12	67.4 ± 0.4	7.8 ± 3.9	24.9 ± 3.5
	Non-Bt	1252 ± 289	100 ± 37	53.7 ± 6.1	15.1 ± 7.1	31.1 ± 1.0
6-June	Bt	1197 ± 124	213 ± 25	72.4 ± 1.5	3.3 ± 0.9	24.3 ± 1.4
	Non-Bt	1032 ± 14	163 ± 5	63.3 ± 5.7	12.1 ± 3.1	24.6 ± 2.6
18-June	Bt	871 ± 112	129 ± 21	74.3 ± 2.4	1.6 ± 0.7	24.2 ± 2.3
	Non-Bt	770 ± 32	104 ± 8	62.8 ± 1.9	10.2 ± 2.4	26.9 ± 1.8
Overall	Bt	1116 ± 106	149 ± 19	71.8 ± 1.5	3.8 ± 1.4	24.4 ± 1.2
	Non-Bt	983 ± 104	120 ± 14	60.4 ± 2.6	12.2 ± 2.1	27.5 ± 1.4
Overall P-values		0.21	0.08	0.002	0.002	0.13

### **Corn**

**Methods:** Five varieties of corn were planted on April 25, 2014 in Starkville, MS. Varieties included 2 non-Bt varieties (DKC64-27 and DKC64-82), a Smartstax variety (DKC64-87) expressing Cry1A.105, Cry1F and Cry2Ab2, a VT3 variety (DKC64-24) expressing Cry1Ab, and a VT2P variety (DKC64-89) expressing Cry1A.105 and Cry2Ab2. Smartstax also had Bt genes active against rootworms. Plots were 8 rows wide by 40 ft long with 4 replications and a 10 ft gap between replicates.

When corn had dried down and was nearing harvest, 20 consecutive ears from one row were examined for tip kernel damage, other kernel damage, and ear feeding that did not appear to damage any kernels. The amount of each type of damage was estimated in cm<sup>2</sup>. Two rows of corn that were not used for any other purpose were harvested from each plot during the normal corn harvest period using a plot combine. Yield, moisture and test weight were recorded.

**Results:** Southwestern corn borer feeding and fall armyworm feeding were not monitored in this trial, but southwestern corn borer pheromone traps caught very few moths at the field, and defoliation was not at a level normally considered to be economically damaging. Corn earworm feeding was the focus of this study. Corn earworm normally feed at the ear tip, but the amount of tip-damaged kernels did not significantly vary (Table 2). Damage at other locations on the ear did vary, with one of the non-Bt varieties having more damage than the other varieties. Ear damage also varied when examining non-kernel damage. In other words, ear tip damage varied on the part of the cob that was not producing kernels anyway. After accounting for kernel or cob damage, there were significantly more ears without visible ear feeding on the Vt Double Pro and Smartstax than on the non-Bt varieties. Most importantly, yield was significantly higher on the Bt varieties than on the non-Bt varieties. Since isolines no longer exist, it is impossible to know how much of this can be attributed to variety vs. the Bt traits, but since it was consistent across all varieties, it is likely that insect protection provided by Bt varieties was responsible for much of the yield differences observed.

Table 2. Harvest data from 2014 Bt- non-Bt corn comparison, Starkville, MS

Bt event	Yield (bu/ac)	No Insect feeding on ear (% ears)	Tip damaged kernels (cm <sup>2</sup> )	Other damaged kernels (cm <sup>2</sup> )	Non-kernel damage (cm <sup>2</sup> )
Check 1	160 ± 5	5 ± 3c	2.9 ± 0.9	1.2 ± 0.3a	2.6 ± 0.7a
Check 2	168 ± 6	21 ± 12bc	2.2 ± 0.3	0.4 ± 0.1b	2.4 ± 0.7a
VT Triple	181 ± 5	17 ± 7bc	3.0 ± 0.5	0.5 ± 0.2b	2.6 ± 1.1a
VT Double Pro	183 ± 4	40 ± 7a	1.4 ± 0.2	0.3 ± 0.1b	1.1 ± 0.6b
Smartstax	180 ± 12	29 ± 14ab	1.9 ± 1.1	0.6 ± 0.2b	0.9 ± 0.7b
Trt P-value	0.143	0.008	0.145	0.010	0.007
Bt vs non-Bt P-value	0.016	0.010	0.290	0.039	0.009

### 2015 Research Plans:

Plans for 2015 are to continue comparing Bt technologies to non-Bt technologies in corn and cotton as done in 2014. To better encompass the variety of agronomic and insect situations facing growers in Mississippi, we plan to place these trials at Brooksville and potentially at Verona as well as at Starkville.

## 2014 Publications and Presentations

### Publications

1. Allen, K.C., M.A. Caprio, K.T. Edwards. 2014. Life table parameters for tarnished plant bug models. *Midsouth Entomologist*. 7(1:Special Issue): 64-75.
2. Allen, K.C., D. Adams, R.G. Luttrell, N.S. Little. 2014. Recent Evaluations of Bt and non-Bt Cotton in the Mississippi Delta. *Proceedings of the Beltwide Cotton Conferences*. New Orleans, LA, p. 886
3. Anathakrishanan, R., D.K. Sinha, M. Murugan, K.Y. Zhu, M. Chen, Y.C. Zhu, and C.M. Smith. 2014. Comparative gut transcriptome analysis reveals differences between virulent and avirulent Russian wheat aphids, *Diuraphis noxia*. *Arthropod-Plant Interactions*. 8(2): 79-88
4. Cook, D., G. Snodgrass, E. Burris, J. Gore, D. Burns, B.R. Leonard. 2014. Area-wide Management Approach for Tarnished Plant Bug in the Mississippi Delta. *Midsouth Entomologist*. 7(1:Special Issue): 29-34.
5. Dobbins, C., J. Gore, D. Cook, A. Catchot, F. Misser, G. Snodgrass. 2014. Tarnished Plant Bug Management in Mississippi. *Proceedings of the Beltwide Cotton Conferences*. New Orleans, LA p.876.
6. Hull, J.J., O.P. Perera, and G.L. Snodgrass. 2014. Cloning and expression profiling of odorant-binding proteins in the tarnished plant bug, *Lygus lineolaris*. *Insect Molecular Biology*. 23(1): 78-97. DOI: <http://doi:10.1111/imb.12064>
7. Kent, S., O.P. Perera, and G.L. Snodgrass. \_\_\_\_\_. Expression profiles of Astakine Genes in *Lygus lineolaris* (Palisot de Beauvois) exposed to fungal spores of *Beauveria bassiana*. *Insect Molecular Biology*. (Submitted August 26, 2014)
8. Little, N., N.A. Blount, M.A. Caprio, and J.J. Riggins. Survey of subterranean termite (*Isoptera: Rhinotermitidae*) utilization of temperate forests. *Sociobiology*. (Submitted November 14, 2013) (Accepted May 23, 2014)
9. Little, N.S., R.G. Luttrell, O.P. Perera. 2014. Challenges to Monitoring Bt Resistance in *Helicoverpa zea* *Proceedings of the Beltwide Cotton Conferences*, New Orleans, LA, p. 699.
10. Luttrell, R.G. and E. King. 2014. Importance of Tarnished Plant Bug as a USDA ARS Research Priority. *Midsouth Entomologist*. 7(1:Special Issue):54-63.

11. Luttrell, R. G., N. Little, and K. C. Allen. 2014. Hophornbeam Copperleaf, an Example Wild Host for *Helicoverpa zea*. In: Proceedings of the Beltwide Cotton Conferences, New Orleans, LA. p.693-698.
12. Olivi, B. D. Cook, J. Gore, A. Catchot, G.L. Snodgrass. Performance of Transform against Selected Cotton Insects in Laboratory and Field Conditions. Proceedings of the Beltwide Cotton Conferences. New Orleans, LA, p. 877.
13. Parys, K.A. \_\_\_\_\_. Current Scientific Literature on Tarnished Plant Bug, *Lygus lineolaris* (Palisot de Beauvois) Ecology in Mississippi and Critical Information Needs. Midsouth Entomologist. (CW received December 19, 2013)
14. Parys, K.A. and K.T. Edwards. 2014. Dedication of Special Issue Honoring Dr. Gordan Snodgrass., Midsouth Entomologist.7(1:Special Issue): 1-2 (Not an ARIS publication)
15. Parys, K.A. and G.L. Snodgrass. 2014. Host plants of the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois). Proceedings of the Beltwide Cotton Conferences, New Orleans, LA. p. 765
16. Parys, K.A., S. Tewari, and S. Johnson. \_\_\_\_\_. The Waterfern Weevil, *Stenopelmus rufinasus* Gyllenhal (Coleoptera: Curculionidae) observed feeding on a non-host plant *Salvinia minima* baker, in the field. The Coleopterists Bulletin. (CW received July 8, 2014) (Submitted July 15, 2014)
17. Perera, O.P., K.S. Shelby, H.J. Popham, F. Gould, M.A. Adang, and J.L. Jurat-Fuentes. \_\_\_\_\_. Generation of a transcriptome in a model lepidopteran pest, *Heliothis virescens*, using multiple sequencing strategies for profiling midgut gene expression. Plos One. (CW received September 8, 2014)
18. Perera, O.P., G.L. Snodgrass, R.G. Luttrell. 2014. Molecular and population genetics of the tarnished plant bug: Current status and future needs. Midsouth Entomologist. 7(1:Special Issue):79-85. (CW received January 16, 2014)
19. Perera, O.P., J. Gore, G.L. Snodgrass, R. Jackson, K.C. Allen, C.A. Abel, R.G. Luttrell. 2015. Temporal and spatial genetic variability among tarnished plant bug, *Lygus lineolaris* (Hemiptera: Mididae)population in a small geographic area. Annals of the Entomological Society of America. 1-12 DOI: 10.1093/aesa/sau016.
20. Perera, O.P., T.K. Walsh, and R.G. Luttrell. \_\_\_\_\_. Complete mitochondrial genome of *Helicoverpa zea* (Boddie) and expression profiles of mitochondrial-encoded genes is early and late embryos. Gene. (Submitted November 25, 2014)
21. Perera, O.P., G.L. Snodgrass, R. Jackson, K.C. Allen, C.A. Abel, R.G. Luttrell. 2015. Temporal and spatial genetic variability among tarnished plant bug, *Lygus lineolaris* (Hemiptera:

- Mididae)population in a small geographic area. *Annals of the Entomological Society of America*. 1-12 DOI: 10.1093/aesa/sau016.
22. Portilla, M. 2014. Biological control as an alternative measure for TPB in Mississippi. *Midsouth Entomologist*. 7(1:Special Issue):29-34.
  23. Portilla, M. G. Snodgrass, and R. Luttrell. 2014. Artificial Diets for life tables bioassays of TPB in Mississippi. *Midsouth Entomologist*. 7(1:Special Issue): 128-135
  24. Portilla, M., G. Snodgrass, and R. Luttrell. 2014. Mississippi Delta Native Strain of *Beauveria bassiana* for control of TPB (*Lygus lineolaris*). *Midsouth Entomologist*. 7(1:Special Issue):114-121
  25. Portilla, M., G.L. Snodgrass, and R.G. Luttrell. 2014. Effects of morning and night application of *Beauveria bassiana* strains NI8 and GHA against the tarnished plant bug in cotton. *Proceedings of the Beltwide Cotton Conferences*, New Orleans, LA. p. 729-734.
  26. Rashid, T., V. Njiti, R. Luttrell and L. Adams. 2014. Effect of Prohexadione-Ca on yield and insect damage to sweetpotatoes. *HortScience*. 49(9): S51.
  27. Riggins, J.J., N. Little, and L.G. Eckhard. 2014. Correlation between infection by ophiostomatoid fungi and the presence of subterranean termites in loblolly pine (*Pinus taeda* L.) roots. *Agricultural and Forest Entomology*. DOI:10.1111/afe.12053 (Submitted August 22, 2014)
  28. Snodgrass, G.L. 2014. Highlights of 30 years of research on TPB in the Mississippi Delta. *Midsouth Entomologist*. 7(1:Special Issue): 3-14. (CW received January 12, 2014)
  29. Zhu, Y.C. 2014. Increased Gene Expressions and Metabolic Detoxifications, a Major Resistance Mechanism to Organophosphate and Neonicotinoid Insecticides in Tarnished Plant Bug. *Midsouth Entomologist*. 7(1:Special Issue):111-113 (Abstract Only)
  30. Zhu, Y.C., C. Blanco, M. Portilla, J. Adamczyk, R. Luttrell, F. Huang. \_\_\_\_\_. Evidence of multiple/cross resistance to Bt and Organophosphate insecticides in Puerto Rico population of the fall armyworm, *Spodoptera frugiperda*. *Pesticide Biochemistry and Physiology*. (Accepted January 12, 2015)

## **Presentations**

1. Adamczyk, J., K. Hackett, T.E. Rindered, R. G. Danka, M. Tarver, Y. C. Zhu, C. Hoffmann, G. Jones, S. Thompson, W. Meilke, J. Ottea, K. Healey, J. Gore, D. Cook, S. D. Stewart, J. A. Skinner, G. Lorenz, A. Catchot. 2013. Launch of the USDA ARE Coordinated project on minimizing the exposure of honey bees to pesticides applied to southern row crops. 60<sup>th</sup> Annual Meeting of the Entomological Society of America, Austin, TX. (Poster)
2. Allen, K. C., D. A. Adams, R. G. Luttrell, and N. Little. 2014. Recent evaluations of Bt and non-Bt cotton in the Mississippi Delta. Beltwide Cotton Conference, New Orleans, LA (January 6-8, 2014).
3. Allen, K.C. 2014. Pollen Analyses of Tarnished Plant Bugs. March 2-5, 2014. Southeastern Branch Meeting of the Entomological Society of America, Greenville, SC.
4. Allen, K.C., R. Luttrell, N. Little, and K.A. Parys. 2014. With-population variability in responses to insecticide bioassays, 61<sup>st</sup> Annual Meeting of the E
5. Cook, D. G. Snodgrass, E. Burris, J. Gore, D. Burns, B. R. Leonard. 2013. Area-wide Management Approach for Tarnished Plant Bug in the Mississippi Delta. Mississippi Entomological Association Meeting
6. Dobbins, C., J. Gore, D. Cook, A. Catchot, F. Musser, G. Snodgrass. 2014. Tarnished Plant Bug Management in Mississippi. Beltwide Cotton Conferences. New Orleans, LA (January 6-8, 2014).
7. Johnson, S.J., M. L. Ferro, A. Meszaros, M. Grodowitz, K. A. Parys, and L. Eisenberg. 2013. Establishment of *Megamelus scutellaris* Berg (Hemiptera: Delphacidae) as biocontrol agent of Common Water Hyacinth (*Eichhornia crassipes* (mart.) Solms) in Louisiana. November 14, 2013. 60<sup>th</sup> Annual Meeting of the Entomological Society of America, Austin, TX. (poster)
8. Little, N., R. G. Luttrell, and O. P. Perera. 2014. Challenges to monitoring Bt resistance in *Helicoverpa zea*. Beltwide Cotton Conference, New Orleans, LA. (January 6-8, 2014).
9. Little, N., D. Adams, K. C. Allen, and R. Luttrell. 2014. Assessing impacts of supplemental control for heliothines on pyramided-Bt and non-Bt cottons. Entomological Society of America, Portland, Oregon, November 16, 2014.
10. Luttrell, R. G. 2014. What are federal agencies doing related to the preventing or deterring the evolution of resistance in agricultural pests in conventional and organic production systems? What could be done? -- USDA-ARS Perspective. National Academy, Board on Agriculture and Natural Resources, Planning Meeting for an Activity on Preventing or Deterring Weed, Insect, and Fungi Resistance to Pesticides, Washington, D. C., September 11, 2014 (invited)

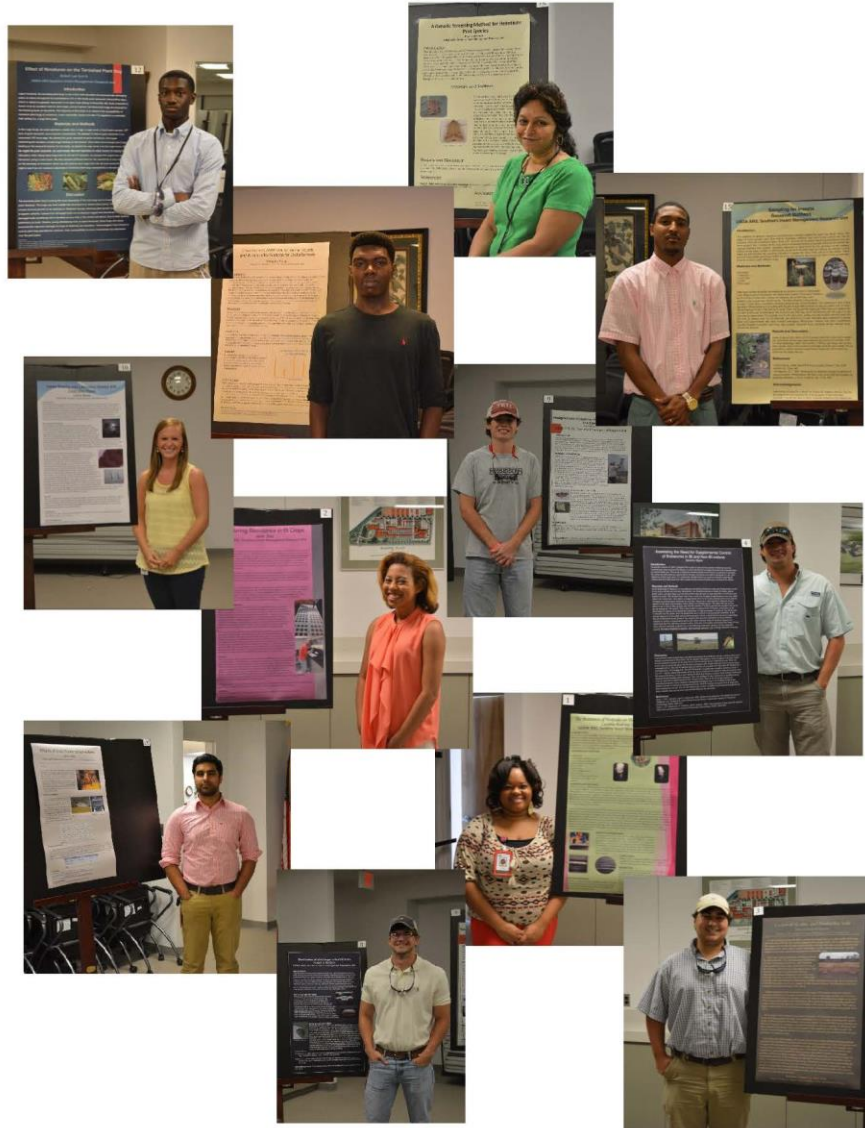
11. Luttrell, R. 2013. Importance of TPB as an ARS Research Priority and Overview of TPB ARS Research Opportunities. Mississippi Entomological Association Meeting, Starkville, MS. October 22, 2013
12. Luttrell, R. G., N. Little, K. Dixon, M. Mullen. 2013. Practical measurement of Bt resistance in heliothines. 60<sup>th</sup> Annual Meeting of the Entomological Society of America, Austin, TX. (Poster)
13. Luttrell, R.G. 2014. Science and Working for the USDA Agricultural Research Service. Greenville Renaissance Scholars, Greenville, MS. (June 27, 2014)
14. Luttrell, R. G., N. Little, and K. C. Allen. 2014. Hophornbeam copperleaf, an example wild host for *Helicoverpa zea*. Beltwide Cotton Conference, New Orleans, LA. (January 6-8, 2014).
15. Luttrell, R. G., N. Little, O. P. Perera, K. C. Allen, M. Portilla, F. R. Musser, D. Cook, and J. Gore. 2014. Monitoring perspective for tobacco budworm and bollworm in the Mid-South. Entomological Society of America, Portland, Oregon, November 16, 2014. (presentation made by Nathan Little)
16. Luttrell, R. G. 2014. Tarnished plant bug research at USDA/ARS. Special Meeting of the Delta Council Advisory Research Committee, B. F. Smith Auditorium, Delta Research and Extension Center, Mississippi State University, Stoneville, Mississippi, December 12, 2014. (invited)
17. Olivi, B., D. Cook, J. Gore, A. Catchot, G. L. Snodgrass. Performance of Transform Against Selected Cotton Insects in Laboratory and Field Conditions. Beltwide Cotton Conference, New Orleans, LA (January 6-8, 2014).
18. Parys, K.A. 2013. Depth of Current Scientific Literature on TPB Ecology in Mississippi and Critical Information Needs. Mississippi Entomological Association Meeting, Starkville, MS. (October 22, 2013) (Poster)
19. Parys, K.A., K.A. Renken, G.L. Snodgrass, and K.C. Allen. Influence of landscape heterogeneity on insecticide resistance in *Lygus lineolaris* (Palisot de Beauvois), March 2-5, 2014. Southeastern Branch Meeting of the Entomological Society of America, Greenville, SC. (Poster)
20. Parys, K.A. and G.L. Snodgrass. 2014. Host plants of the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois). 60<sup>th</sup> Annual Meeting of the Entomological Society of America, Austin, TX. (Poster)
21. Parys, K. A. and G. Snodgrass. 2014. Host plants of the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois). Beltwide Cotton Conference, New Orleans, LA. (January 6-8, 2014). (Poster)

22. Perera, OP. 2013. Understanding TPB Genetics and Population Structure in Mississippi. Mississippi Entomological Association October 22, 2013.
23. Perera, OP., J. Gore, G. Snodgrass, R. Jackson, K.C. Allen, C. A. Abel, R. Luttrell. 2013, Temporal and spatial genetic variability of the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvoise), populations in a small geographic area. 60<sup>th</sup> Annual Meeting of the Entomological Society of America, Austin, TX.
24. Portilla, M., G. Snodgrass, and R. G. Luttrell. 2014. Effects of morning and night applications of *Beauveria bassiana* strains NI8 and GHA against the tarnished plant bug in cotton. Beltwide Cotton Conference, New Orleans, LA. (January 6-8, 2014).
25. Portilla, M. 2013. Alternative Control Measures for TPB in Mississippi. Mississippi Entomological Association October 22, 2013.
26. Portilla, M., G. Snodgrass, R. Luttrell. 2013. Effect of solar radiation on the effectiveness of *Beauveria bassiana* infection in *Lygus lineolaris*. 60<sup>th</sup> Annual Meeting of the Entomological Society of America, Austin, TX. (Poster)
27. Portilla, M., H. Abbas, C. Accinelli, and R. Luttrell. 2014. Evaluation of *Beauveria bassiana* spores compatibility with bio-plastic surfactant to control tarnished plant bug (*Lygus lineolaris*) in cotton. Entomological Society of America, Portland, Oregon, November 16, 2014.
28. Rashid, T. 2014. Comparison of different organic sweetpotato varieties for local adaptation. In-field presentation, Mound Bayou, MS.
29. Rashid, T. 2014. Integrated pest management (IPM) adoption by small farms in Mississippi. In ASU annual Agricultural Research & Extension Field Day Publication.
30. Rashid, T., V. Njiti, R. Luttrell and L. Adams. 2014. Effect of Prohexadione-Ca on yield and insect damage to sweetpotatoes. National Sweetpotato Collaborators Group annual meeting in Dallas, TX. January 2014.
31. Rashid, T., P. McLeod and R. Luttrell. 2014. Efficacy of different insect traps in sweetpotatoes. 62nd Annual Meeting of Entomological Society of America in Portland, OR. November, 2014.
32. Rashid, Tahir, P. J. McLeod, and R. Luttrell. 2014. Insect monitoring in sweetpotato. Southeastern Branch, Entomological Society of America, Greenville, South Carolina, March 3, 2014.
33. Snodgrass, G.L. 2013. Highlights of 30 years of research on TPB in the Mississippi Delta. Mississippi Entomological Association October 22, 2013.

34. Zhu, Y.C., J.J. Adamczyk, and R.G. Luttrell. 2014. What you should know about pesticides: Which is more toxic and which is relatively safer to your honeybees. Arkansas Beekeepers Association Annual Conference. Mountain View, AR. October 9-12, 2014. (CW received October 23, 2014)

## Appendix A

### *SIMRU's 2014 Pathway Interns/LA Appointments Employees*



**Top left to right:** Robert Hurt, Padmapriya Chatakondi, Mamadou Fadiga, Roosevelt Matthews, Laura Sipes, Jaret Reister, Jana Slay, Severino Signa, Faizan Tahir, Cavishia Roberson, Russell Godbold, and John-Austin Coleman. **Not pictured:** Julian Beamon, Maria Benavides, Marcus Cannon, Raksha Chatakondi, Austin Henderson, Julian Henry, Gerard Winters, and Brice Zeigler.